SEEKING CLOCKS IN THE CLOUDS:

NONLINEARITY AND AMERICAN PRECISION AIR POWER

by

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Abstract

Despite our best scientific intentions, the world remains an inherently complex and unpredictable place. This dissertation explores the American penchant for science and technology and its impact on the development of American precision air power. Throughout their short history, American airmen, in an effort to overcome the pervasive uncertainty of war, have sought greater precision in their air-to-ground weapons, as well as in their plans for employing these weapons. This mechanistic approach to air warfare, however, has not rid air operations of ambiguity and irregularity. As the historical case studies in this dissertation show, an overly-engineered approach has often only further amplified the negative manifestations of nonlinearity. Given the continuing existence of irregularity despite increasing technological sophistication, this study recommends the application new paradigm to air warfare, a paradigm drawn from the modern sciences of chaos and complexity to replace the determinism of the Newtonian science. With its closer analytical fit to the realities of air warfare, a nonlinear analytical paradigm can both improve our understanding of the past, as well as assist us in better preparing for air problems of the future.

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The Challenge of Nonlinearity

"These particles at times – no one knows when or where – they swerve a little, not much, but just enough for us to say they change direction."

Lucretius, *De Rerum Natura*[1]

Success in war, as in other social endeavors, demands control over outcomes. Victory requires making the effects of military actions match our expectations. Predominance alone – in forces, technology, and destructive capability – is no guarantee of military success. The frustration of American objectives in Vietnam and the lingering conflicts in Iraq and Afghanistan attest to the fundamental importance, and the perpetual difficulty, of controlling military outcomes.

The ultimate source of these frustrations lies in the nature of war itself, specifically in its *nonlinearity*. Our minds, conditioned to think linearly, are ill-equipped for the inherently nonlinear world around us. Although we expect future end states to be linear projections of past sequences, this is seldom the case. In a nonlinear world where outputs are seldom proportional to inputs, irregularity and disorder – not regularity and order – predominate. Precise prediction of outcomes – *tracing the connection between applied causes and future effects* – becomes extraordinarily difficult.[2] And of all human affairs, war is perhaps the most nonlinear and effectively indeterminate. Although we may wish to dictate the outcomes of war, we rarely know all of the relevant variables, to say nothing of our ability to quantify their values; we can only haphazardly guess at the

[1] Titus Lucretius Carus, *De Rerum Natura* (The Way Things Are), Book II, Rolfe Humphries, trans. (Indiana University Press, 1968), 219-220.
[2] On causality, prediction, and the philosophy of science in a nonlinear world, see John L. Casti, *Searching for Certainty: What Scientists Can Know About the Future* (New York: William Morrow and Company, Inc., 1990), especially 19-76.

governing equations that link these "independent" variables to the "dependent" variable we seek to affect.[3] "The art of war" observed Clausewitz, "...must always leave a margin for uncertainty, in the greatest things as much as the smallest."[4]

This dissertation examines how the nonlinear nature of war has influenced the ideas, the technologies, the people, and the organizations behind American precision air power. Although technology has played a leading role in air power's evolution, technology is only meaningful within its cultural, operational, and political context.[5] American airmen, conditioned by their cultural heritage, have invariably turned to technology and "engineered" solutions to the problems of war. Understanding these engineered approaches and how they have alternatively failed and succeeded is a primary objective of this study. A second objective is to confirm the continuing indeterminacy of war in the modern era and demonstrate the relevance and applicability of the new nonlinear paradigm to military studies.

The clock, symbolic of precision air power, represents a fundamental outlook that blossomed in the West during the Scientific Revolution - the belief that man could harness the untidy processes of nature (like time) through applied science and technology.[6] As a device contained entirely within itself, the clock represents the

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[3] See Timothy Sakulich, *Precision Engagement at the Strategic Level of War: Guiding Promise or Wishful Thinking*, Occasional Paper No. 25 (Maxwell Air Force Base, AL: Air University, December 2001), 17.
[4] Carl von Clausewitz, *On War*, Michael Howard and Peter Paret, eds. and trans. (Princeton: Princeton University Press, 1976), 86.
[5] Colin Gray, *Weapons for Strategic Effect: How Important is Technology?* (Maxwell AFB, AL: Air University Press, 2001), 31-32.
[6] As early as 1637, Rene Descartes claimed that we should one day be able to describe the operation of a tree just like we do the operation of a clock. Stephen Wolfram, *A New Kind of Science* (Champaign, IL: Wolfram Media, Inc., 2002), 861. The analogy of clocks and clouds is taken from Karl Popper's comparison of deterministic and indeterminate systems. See Karl R. Popper, "Of Clouds and Clocks: An Approach to the Problem of Rationality and the Freedom of Man," in Popper, *Objective Knowledge: An Evolutionary Approach* (Oxford: Clarendon Press, 1972). Gabriel Almond and Stephen Genco further expand on Popper's metaphor by applying it to the problems of the formal, scientific approach to

rational, Western view of technological devices as closed systems operating in predictable, deterministic ways despite fluctuation and change in the surrounding environment. It stands for the mechanistic approach to man's relationship with the natural world, a desire to divide continuous and interrelated processes into neat and distinct groupings to create the scientific vision of "a universe of order."[7]

But even the mechanical clock can be less deterministic than one might think. Batteries run down, parts break or malfunction, and inputs from outside the "closed" system of the clock (the alarm clock knocked off the bedside table) prevent precise and predictable function. The outcomes of the processes of a clock may be more predictable than for other, less deterministic processes, but these outcomes are nevertheless a matter of probabilities only and are never guaranteed.[8] As quantum theory and the new nonlinear sciences have shown, indeterminacy and chance are fundamental to all natural processes, to include man's application of technology to his surrounding environment. In the words of Karl Popper, *"...all clocks are clouds...only clouds exist, though clouds of very different degrees of cloudiness."*[9]

Clouds thus represent what Albert Hirschman calls "the multiplicity and creative disorder of the human adventure."[10] Although indeterminate in shape, clouds are anything but random, that is, without regularities. Within their varying forms are numerous repetitions and similarities, identifiable patterns that nonetheless never repeat

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indeterminate social phenomena. See Gabriel A. Almond and Stephen J. Genco, "Clouds, Clocks, and the Study of Politics," *World Politics* 29/4 (July 1977).

[7] Joel Davis, *Alternate Realities: How Science Shapes Our Vision of the World* (New York: Plenum Press, 1997), 9. Davis highlights the common element of *vision* in both science and poetry and the importance of scientific metaphor in shaping our understanding of the surrounding world.

[8] Almond and Genco, 490-491.

[9] Popper, "Of Clouds and Clocks," 213.

[10] Albert O. Hirschman, *A Bias for Hope* (New Haven: Yale University Press, 1971), 27. Quoted in Almond and Genco, 517.

in exactly the same way. Clouds thus represent the open-ended, dynamic and inevitably messy environment and the irregularity of the effects of our actions within this environment.[11] The cloud is the variation that so frustrates our technocratic efforts to simplify and control the inherently unwieldy dynamics of social and political interaction.[12]

Proceeding from this metaphorical context, this study surveys how American airmen have sought to build precise and deterministic "clocks" in the "cloudy" environment of war. Much in air warfare *is* clocklike and susceptible to technological control. The new paradigm alone, therefore, can't offer definitive solutions to the problems of air warfare. As a complement or extension to Newtonian science, however, the nonlinearity of the new sciences of chaos and complexity can help airmen better understand, describe, envisage, and "manage" what is possible for war from the air.[13]

Precision Air Power

Precision air power consists of a series of tactical and technological innovations in finding, tracking, and stealthily striking military targets from the air.[14] A modern

[11] Popper offers "a different view of the world – one in which the physical world is an open system. This is compatible with the view of the evolution of life as a process of trial-and-error elimination; and it allows us to understand rationally, though far from fully, the emergence of biological novelty and the growth of human knowledge and human freedom." Popper, "Of Clouds and Clocks," 254-255.
[12] Almond and Genco write: "The implication of these complexities of human and social reality is that the explanatory strategy of the hard sciences has only a limited application to the social sciences. Models, procedures, and methodologies created to explore a world in which clocklike and cloudlike characteristics predominate will capture only a part of the much richer world of social and political interaction." Almond and Genco, 493.
[13] As Fritjof Capra writes, "[M]odern science has come to realize that all scientific theories are approximations to the true nature of reality; and that each theory is valid for a certain range of phenomenon. Beyond this range it no longer gives a satisfactory description of nature, and new theories have to be found to replace the old one, or, rather, to extend it by improving the approximation." Fritjof Capra, *The Turning Point* (New York: Bantam Books, 1982), 101.
[14] For a discussion of modern understandings of air power in both the broad ("a pervasive attribute of modern military forces; that form of military power generated by platforms capable of sustained,

expression of the technocratic approach to war, precision air power includes not only the aerial platforms and guided munitions that deliver lethal fire from the air, but also the supporting technological systems of intelligence, surveillance, command and control, and stealth that enable precision strikes.[15] The speed, range, flexibility, precision, perspective, and lethality inherent to air power make it a popular tool for political and military strategists alike.[16]

The popularity of air power is not limited to the United States Air Force alone. The Navy's force structure centers on the carrier battle group, the Marines around the air-ground task force, and the Army's aviation branch, with its 5000 attack and lift helicopters, is the largest air arm in the world.[17] Air power is a vital component in each element of Admiral Bill Owens' "system of systems" – air breathing platforms perform the bulk of intelligence, surveillance, and reconnaissance missions, provide communications links across the battlefield, and are a primary means for delivery of

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maneuvering, powered flight") and more narrow ("the ability to deliver lethal fire power from the air") sense, see Eliot Cohen, "The Meaning and Future of Air Power," *Orbis*, 39/2 (Spring 1995), 189ff.

[15] The widely diffused roots of our technocratic approach to warfare lie much deeper than the development of satellites and laser-guided bombs in the late twentieth century. Arden Bucholz gives one example of how new technologies shaped approaches to war from the 19th century: "[the] impact of the railroad in war planning was that mechanical regularity began to triumph over natural irregularity. The replacement of animal and human power by steam power in one stage of the war plan assumed the guise of guarantee for the whole plan. The natural irregularities of the terrain were replaced in the planner's mind by the sharp linearity of the railroad. A machine ensemble had injected itself between the railroad and the land: war planners now began to think about the land as it was filtered through the machinery." Bucholz, "Armies, Railroads, and Information," 61.

[16] David Deptula, *Effects-Based Operations: Change in the Nature of Warfare* (Arlington, VA: 2001), 25.

[17] Phillip S. Meilinger, "Air Strategy: Targeting for Effect," *Aerospace Power Journal* (Winter 1999), 60.

"precision force."[18] Air power, a seemingly low cost, low risk means of achieving objectives, has become a key ingredient in the American formula for war.[19]

From its earliest conception, proponents of precision air power have asserted that the increased technological accuracy of air weapons has changed the very nature of war. Precise weapons, supported by precise knowledge about targets and the effects of destroying these targets, can make war not only more controllable, but also more humane. By applying "precisely measured power directly against specific elements of hostile strength," accurately delivered air power removes the need to defeat "opposing armed forces as a prerequisite to conducting operations directly against an opponent ... either in his sovereign territory or in any other locality."[20] The current U.S. Air Force vision statement advertises air power's ability "to strike effectively wherever and whenever necessary with minimum collateral damage," a capability that "harness[es] new ways to achieve desired effects."[21] *Precision engagement* – "the ability ...to cause discriminate strategic, operational, or tactical effects" – has graduated in the most recent Air Force doctrine from a core competency to a "distinctive capability" that is the "scalpel" of U.S. military operations.[22]

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[18] William A. Owens, *Lifting the Fog of War* (New York: Farrar, Strauss, and Giraux, 2000), 98-102. See also William A. Owens, "The Emerging System of Systems," in Stuart Johnson and Martin Libicki, eds., *Dominant Battlespace Knowledge* (Washington, D.C.: NDU Press, 1995); and John A. Warden, III, "Employing Air Power in the Twenty-first Century," in Richard H. Shultz, Jr. and Robert L. Pfaltzgraff, Jr., eds., *The Future of Air Power in the Aftermath of the Gulf War* (Maxwell AFB, AL: Air University Press, 1992), 61-62.
[19] Phil Meilinger, for example, has asserted, "Aerospace power... should be our weapon of choice because it is the most discriminate, prudent, and risk-free weapon in our arsenal." Phillip S. Meilinger, "Precision Aerospace Power, Discrimination, and the Future of War," *Aerospace Power Journal* 15 (Fall 2001), 12.
[20] *Air Force Manual 1-2, United States Air Force Basic Doctrine* (Washington, D.C.: Department of the Air Force, 1 December 1959), 13.
[21] *Global Vigilance, Reach, and Power: America's Air Force Vision 2020.* Online at http://www.af.mil/library/posture/vision/ (accessed 20 October 2004).
[22] Sheila E. Widnall and Ronald R. Fogelman, *Global Engagement: A Vision for the 21st Century Air Force* (Washington, D.C.: Headquarters Air Force, November 1996). *Air Force Doctrine Document 1, Air Force Basic Doctrine* (Washington D.C.: Government Printing Office, September 1997), 30. *Air Force Doctrine*

Precision air power – the measured application of military force from the air for discriminate effects – plays to the American proclivity for efficient technological solutions and control over the untidy dynamics of war.[23] "A nation of machine makers and system builders," writes historian Thomas Hughes, "[Americans] became imbued with a drive for order, system, and control."[24] Although many air forces have sought greater accuracy in the delivery of weapons, the ways in which Americans have gone about it – the methods they have pursued, the alternatives they have foregone, the resources they have developed, the capabilities they have deemed important – are uniquely American. New technologies in surveillance and targeting, stealthy delivery, and precision strike, with their potential for lifting the Clausewitzean fog shrouding military and political objectives, are form-fitted to the American preference for technological solutions.[25]

Document 1, Air Force Basic Doctrine (Washington D.C.: Government Printing Office, 17 November 2003), 80. *The USAF Transformation Flight Plan 2004* describes precision engagement as a transformational capability enabled by precision-guided munitions. *The United States Air Force Transformation Flight Plan 2004* (Washington, D.C.: Headquarters USAF, 2004), 60-62. For an analysis of the role of precision air power in joint and Air Force doctrine, see Keith J. Kosan, *United States Air Force Precision Engagement Against Mobile Targets: Is Man in or Out?* (Maxwell Air Force Base, AL: Air University Press, November 2001), 10-12.

[23] See especially Michael Sherry, *The Rise of American Air Power: The Creation of Armageddon* (New Haven, CT: Yale University Press, 1987); and Donald R. Baucom, "Technological War: Reality and the American Myth," *Air University Review* (September-October 1981). One recent analyst describes this proclivity as "a public enthusiasm for the whiz-bang technology of the U.S. military that is almost boyish." David Skinner, "The New Face of War," *The New Atlantis* 2 (Summer 2003), 44.

[24] Thomas P. Hughes, *American Genesis: A Century of Technological Enthusiasm, 1870-1970* (New York: Viking, 1989), 1.

[25] See especially Owens, *Lifting the Fog of War* and Owens, "The Emerging System of Systems." The claim that technology can reduce the uncertainty of war is not limited to Navy and Air Force thinkers. "The key to understanding the new "truths" of modern warfare lies in grasping the combined impact of the new battlefield lethality and battlefield visibility. Increases in both of these battlefield factors greatly affect the "precision" with which we can fight. Increased lethality allows targets to be engaged much more precisely than before at extended ranges. Increased battlefield "visibility" – provided by enhanced C3I – allows us to grasp the battle much more precisely and quickly. Thus, technology has made warfare much more certain and precise than was ever thought possible." Richard I. Dunn, III, *From Gettysburg to the Gulf and Beyond: Coping With Revolutionary Technological Change in Land Warfare.* McNair Paper No. 13 (Washington, DC: National Defense University, March 1992), 39. Online at http://www.ndu.edu/inss/macnair13/macnair13.pdf (accessed 12 September 2003). On the "revolution in military affairs" (RMA) and the hypothesis that new technologies will fundamentally change the nature of

A recent newspaper ad from a leading American defense firm exemplifies this view:

> "Only [our firm] has the vision and technology to transform the chaos of warfare into clarity. Our advanced battle management systems enable the real-time integration of a complex array of command, control, communications, and intelligence assets. This information superiority lets military planners shape the battle space and deploy forces faster and more flexibly. It enables total domination throughout: on the ground, at sea, in the air, space, and cyberspace."[26]

The general belief that precision technology has changed the very nature of warfare, making it a more deterministic and controllable venture, has also become a basic tenet of American air power theory. As air theorist John Warden put it:

> Precision weapons allow the economical destruction of virtually all targets—especially strategic and operational targets that are difficult to move or conceal. *They change the nature of war from one of probability to one of certainty.* Wars for millennia have been probability events in which each side launched huge quantities of projectiles (and men) at one another in the hope that enough of the projectiles (and men) would kill enough of the other side to induce retreat or surrender. Probability warfare was chancy at best. It was unpredictable, full of surprises, hard to quantify, and governed by accident. Precision weapons have changed all that. In the Gulf War, we knew with certainty that a single weapon would destroy its target. War moved into the predictable.[27]

As one pundit has put it: "*With precision warfare the commander has a rifle that cannot miss.*"[28]

There is more to the American doctrine of precision warfare than just the accurate delivery of projectile weapons from the air. "Precision engagement," notes *Joint Vision*

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war, as well as a critique of "the Owens thesis," see Michael O'Hanlon, *Technological Change and the Future of Warfare* (Washington, D.C.: The Brookings Institution, 2000) and Eliot Cohen, "A Revolution in Warfare," *Foreign Affairs* 75/2 (March/April 1996), 37-55.

[26] Advertisement for the Northrup Grumman Corporation in *The Washington Post*, 9 September 2003, A20. See also http://www.northgrum.com/images/ads/print_ads/cor-133m-03_2020.pdf.

[27] John A. Warden, III, "Air Theory for the Twenty-first Century," in Barry R. Schneider and Lawrence E. Grinter, eds., *Battlefield of the Future: 21st Century Warfare Issues.* (Maxwell AFB, AL: Air University Press, 1995), 119. Italics added for emphasis.

[28] Dunn, 48. Italics in the original.

2020, "extends beyond precisely striking a target with explosive ordnance."[29] Precise military operations also involve *analytical* precision or the ability to accurately determine and control the relationship between applied cause and aggregate effect. "Effects-based operations," now an important theoretical paradigm throughout the U.S. military, explicitly ties precision targeting at the tactical level to the achievement of strategic and political outcomes.[30] Precision warfare is more than hitting what one shoots at – it is also shooting at the right thing. According to a leading advocate of effects-based warfare, Air Force Major General David Deptula, by applying "dominant battlefield knowledge" to identify targets and precision strike capabilities to destroy them, the U.S. military can "fire for effect," achieving certainty of tactical outcomes without undesired or unintended strategic effects.[31]

Precision warfare, therefore, involves more than just technological improvements – it is an enduring attitude about the possibilities of knowledge and control that has captured the imagination of military professionals. It embodies a belief that, with

[29] *Joint Vision 2020* defines "precision engagement" as "the ability of joint forces to locate, surveil, discern, and track objectives or targets; select, organize, and use the correct systems; generate desired effects; assess results; and reengage with decisive speed and overwhelming operational tempo as required, throughout the full range of military operations." *Joint Vision 2020*, 22-23. Christopher Warner defines precision engagement as "A JV 2010 [*Joint Vision 2010*] operational concept that consists of target locations, effective command and control, accurate weapons delivery, and efficient weapons effects." Christopher Warner, *Implementing Joint Vision 2010: A Revolution in Military Affairs for Strategic Air Campaigns* (Maxwell Air Force Base, AL: Air University Press, 1999), 78.

[30] See Edward C. Mann III, Gary Endersby, and Thomas R. Searle, *Thinking Effects: Effects-based Methodology for Joint Operations* (Maxwell AFB, AL: Air University Press, 2002). See also Deptula, *Effects-Based Operations*, 8-9 on precision air power as the enabling agent in effects-based ops. The theory of effects-based operations is discussed in detail in chapter 6.

[31] See David Deptula, "Firing for Effects," *Air Force Magazine* (April 2001), 46-53. Another example of this attitude taken from emerging doctrine: "Precision extends beyond surgical strikes to the exact application of all joint force capabilities to achieve greater success at less risk. Knowledge gained in all dimensions will enhance the capability of the JFC to understand a situation, determine the effects desired, select a course of action and the forces to execute it, accurately assess the effects of that action, and reengage as necessary. Regardless of its application in combat or non-combat operations, the capability to engage precisely allows commanders to shape situations or battle space in order to generate the desired effects while minimizing unintended effects and contributing to the most effective use of resources." Department of Defense, *Draft Capstone Concept for Joint Operations* (14 June 2005), 22-23.

technologies for finding, tracking and eliminating discrete targets, the military will be able to more accurately measure the effects of their actions on chosen targets and their surrounding environment.[32] This belief in precision implies a faith not only in the ability to destroy and tally targets at the tactical level, but also in the ability to formulate plans to achieve discriminate outcomes at the strategic or political level.[33] It suggests a confidence in new technological capabilities that will in the end allow the military to master the unruly and disobedient processes of war. It is the continuation of the age-old struggle to overcome what one historian has called "the persistent, recalcitrant indecisiveness of war."[34] Its articulation as precision air power is an extension of the century-long quest for definitive causal relationships between aerial attacks and desired political outcomes, an aspiration that one analyst has called "the Holy Grail of airpower theory."[35]

Aerially delivered weapons with near perfect accuracy have indeed provided real military benefits. Greater precision reduces collateral damage (defined in joint doctrine as the "unintentional or incidental injury or damage to persons or objects that would not

[32] As Phil Meilinger notes, "Americans seem to have a cultural penchant for measuring things, especially in war – bomb tonnage, sortie rates, body counts, tank kills – and this can beguile one into thinking the mere presence of numbers implies either accuracy or success." Meilinger, "Air Strategy: Targeting for Effect," 60.

[33] "Above all, PGMs [precision guided munitions] connect political objectives to military execution with much greater reliability than ever before. The political leader can have far greater confidence that discrete objectives can be met and can thus gain broader latitude in formulating the overall objective. This is not just a change in air power or even military power; it is a fundamental change in warfare." Charles Boyd and Charles M. Westenhoff, "Air Power Thinking: Request Unrestricted Climb," *Airpower Journal* (Fall 1991). Available at http://www.airpower.au.af.mil/airchronicles/apj/boyd.html (accessed 25 September 2003).

[34] Russell F. Weigley, *The Age of Battles: The Quest for Decisive Warfare from Breitenfeld to Waterloo* (Bloomington: Indiana University Press, 1991), 537. Countering Weigley while echoing a similar sentiment, Colin Gray writes that "wars' outcomes typically have a significant power of decision, if not always the decisions intended, even by the victor." Colin S. Gray, *Defining and Achieving Decisive Victory* (Carlisle, PA: Strategic Studies Institute, April 2002), 9.

[35] Peter Faber, "Competing Theories of Airpower: A Language for Analysis." Available at http://www.airpower.au.af.mil/airchronicles/presentation/faber.html (accessed 25 September 2003).

be lawful military targets in the circumstances ruling at the time").[36] Precision air power also allows airmen to think about hitting target sets previously inaccessible, and then to attack these targets using fewer sorties and fewer aircraft. In World War II, hundreds of bombers dropped thousands of tons of bombs over several missions to destroy an industrial district; in Kosovo, a single B-2 bomber armed with precision-guided bombs could strike several individual targets in a single pass. Precision, as military theorists now frequently note, has essentially redefined the concept of mass.[37]

Aerial imprecision, however, has also been useful throughout history, especially when the target is popular will to continue the struggle, as with British area bombing of German cities or American firebombing in Japan during World War II.[38] But given the tactical efficiencies of weapons' accuracy and contemporary standards of morality and international law, it is hard to imagine a modern air force that would set out to be deliberately imprecise. Even area or firebombing was aimed at some point on the ground, and the closer to that point that bombs could be dropped, the better. Improved technical accuracy does offer real advantages to air power.

While there are many benefits to greater accuracy, unqualified control over the strategic and political outcomes of war is not one of them. More accurate strikes may make the immediate tactical effects of bombing more predictable. But because war is nonlinear, accurately delivering bombs will not always directly translate to the accuracy

[36] "Collateral Damage" in Joint Publication 1-02, *DOD Dictionary of Military and Associated Terms* (9 June 2004). Online at http://www.dtic.mil/doctrine/jel/doddict/index.html. (Accessed 25 October 2004).
[37] Phillip S. Meilinger, *10 Propositions Regarding Air Power* (Washington D.C.: Air Force History and Museums Program, 1995), 41-48. See also Deptula, *Firing for Effects.*
[38] On this point, see also John F. Peters, "A Potential Vulnerability of Precision-Strike Warfare?" Orbis (Summer 2004), 479-487 Peters, considering U.S. difficulties in Iraq, asks: "Could it be that coalition forces did not kill enough Iraqis to demoralize them and cause them to submit to coalition occupation? ... [W]hat if precision warfare has the sociology of war wrong? What if it fails to produce submission in the enemy society?"

and precision of higher order effects. Precision air power may be efficient, but tactical efficiency is not the same as strategic effectiveness.[39] Throughout the history of American air power, making this direct translation from tactical and operational virtuosity to strategic outcomes has been relatively easy in theory, but much harder to carry out in practice. Despite increasing levels of technological sophistication, air war remains an untidy and imprecise business.

War and Nonlinearity

War, more than any other social phenomenon, is governed by nonlinear dynamics, where small inputs lead to disproportionately large effects.[40] War is a matter of probabilities influenced, but not determined, by the actors involved and the nature of the surrounding environment.[41] Although war is not a stochastic phenomenon with entirely random outcomes, it is an effectively indeterminate process with essentially incomputable dynamics. In the words of Napoleon, "Newton himself would quail before the algebraic problems it could pose."[42]

A process is linear where outputs change proportionally with changes in inputs. If an input doubles, then the output will likewise double; similarly, if the input is cut in half,

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[39] On the difficulties of translating tactical and operational precision to strategic effectiveness, see especially Timothy R. Reese, "Precision Firepower: Smart Bombs, Dumb Strategy," *Military Review* (July-August 2003), 46-54.

[40] In describing war as a nonlinear phenomenon, this study addresses the functional or mathematical linearity of military operations and not geometric linearity as in linear formations of opposing troops or frontages on the battlefield. Although the increasingly fluid and geometrically nonlinear nature of the modern battlefield may be a result of the increasing dynamical nonlinearity of the processes of war, it is a different subject for analysis. See John F. Schmitt, "Command and (Out of) Control: The Military Implications of Complexity Theory," in Alberts and Czerwinski, *Complexity, Global Politics, and National Security*, 223; and Eileen Bjorkman, et ali., *Air Campaign Course* (Maxwell AFB, AL: Air Command and Staff College, 1993), 38.

[41] On the unpredictability of nonlinear social processes, see Robert Jervis, *Systems Effects: Complexity in Political and Social Life* (Princeton: Princeton University Press, 1997), especially 34-39. See also Gustaaf Geeraerts, "Non-linear Dynamics and the Prediction of War," *Pole Paper Series* 4/1 (January 1998), 6-7.

then output will also be halved. If aerial bombing was a linear phenomenon, doubling the quantity of bombs dropped would double the resulting effects (twice as many buildings destroyed, leaders swayed, people demoralized). A linear process also obeys the principle of additivity or superposition – the whole is always equal to the sum of the individual parts.[43] Because linear systems follow the principles of proportionality and superposition, their analysis can therefore be reduced to the analysis of individual components. Time for such a mechanistic system is analytically "reversible," that is, given information about the state of a system at any time, it is possible to deduce not only what the system will do in the future, but also what it has done in the past.[44] In short, linear processes are regular, deterministic – "if this, then that" – and therefore predictable, making it possible to link actions directly to desired effects.

Despite our best wishes, however, most of the processes man seeks to control (like war and the weather) are relentlessly nonlinear.[45] Not only can small differences in

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[42] Quoted in Clausewitz, *On War*, 586.

[43] In a more extensive definition of linearity, Tom Czerwinski writes: "The features of linearity include *proportionality, additivity, replication,* and *demonstrablity of causes and effects.* With *proportionality,* small inputs lead to small outputs, greater inputs to larger consequences in an environment where these causes and effects are demonstrably and effectively measurable. Like the linear mathematical equation, only one valid answer is possible, permitted, or expected. Further, the linear principle of *additivity* provides that the whole is equal to the sum of its parts. This promotes and legitimizes *reductionism,* the practice of taking a complicated and large problem and breaking it into more manageable pieces, analyzing the constituent parts, and arriving at a conclusion. The assumption, of course, is that the cumulative analytic product represents a valid derivative of the original whole, faithful and more complete. *Replication* means that the same action or experiment under the same conditions will come out the same way; that results are repeatable, and therefore, independently verifiable. Finally, *cause and effect are demonstrable.* This can happen in a number of ways: observed, inferred, extrapolated, statistically validated, and so on. Therefore, the nature of linear systems is that if you know a little about their behavior, you know a lot. You can extrapolate, change scales, and make projections with confidence. Unlike nonlinearity, in which 2+2 may yield oranges, in linearity you can rely on the 4." Tom Czerwinski, *Coping With the Bounds: Speculations on Nonlinearity in Military Affairs* (Washington D.C.: National Defense University, 1998), 8-9.

[44] Wolfram, *A New Kind of Science*, 435. See also Ilya Prigogine, *Order Out of Chaos: Man's New Dialogue With Nature* (New York: Bantam Books, 1984), xix and 57-62.

[45] For a short, well-written explanation of nonlinearity, see especially Barry Watts, *Clausewitzean Friction and Future War*, McNair Paper 52 (Washington DC: National Defense University, October 1996) (Revised July 2000), 110-112. See also Ian Stewart, *Does God Play Dice? The New Mathematics of Chaos* (Malden, Massachusetts: Blackwell Publishers, Inc., 2002), 72-74; and Frans Osinga, *Science, Strategy, and War:*

input lead to large changes in output, but also large inputs might have a disproportionately small or no effect. In a nonlinear combat environment, for example, despite the magnitude of the effort, our actions may ultimately lead to naught. Stated mathematically, an equation is nonlinear where it contains a variable with an exponent other than one.[46] A mathematical formula is also nonlinear where there is iteration, that is, where the dependent variable feeds back into itself.[47]

Because air power is as much a matter of qualities as it is quantities, it is important to move beyond a mathematical statement of nonlinearity toward a better *qualitative* grasp of its sources and effects. Nonlinear dynamics are best understood qualitatively through two concepts: *contingency* and *interaction*.[48] Contingent processes are extremely sensitive to changes in their initial conditions, a defining characteristic of chaos.[49] The outcome of a nonlinear process depends upon the precise conditions that

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The Strategic Theory of John Boyd (Delft, Netherlands: Eburon Publishers, 2005), 94-95. For a concise comparison of linear and nonlinear behaviors, see Ian Marshall and Danah Zohar, *Who's Afraid of Schrodinger's Cat?* (New York: William Morrow, 1997), 249-250.

[46] *The American Heritage College Dictionary*, 3rd ed. (Boston: Houghton Mifflin Co., 1993), 928.

[47] See Roderick V. Jensen, "Classical Chaos," *American Scientist* 75 (March-April 1987), 168-181 for demonstrations of chaos in mathematical equations. One equation used to illustrate the mathematical properties of nonlinearity is the "logistics mapping equation" where $x_{next} = kx(1-x)$. Biologists originally used this equation to study the growth of populations in place of the linear, Malthusian scenario of unrestrained growth. James Gleick, *Chaos: Making a New Science* (New York: Penguin Books, 1988), 59-80, John L. Casti, *Complexification: Explaining a Paradoxical World Through the Science of Surprise* (New York: HarperCollins Publishers, 1994), 93-94 and Ian Stewart, *Does God Play Dice?*, 145-146.

[48] In the language of dynamical systems theory, contingency is associated with changing initial conditions and interaction with changes in a system's vector field. See Casti, *Searching for Certainty*, 62-63.

[49] Ziauddin Sardar and Iwona Abrams, *Introducing Chaos* (Cambridge, England: Icon Books LTD, 1999), 26. The *American Heritage College Dictionary* gives several meanings for the word "contingency," two of which are: "The conditions of dependence on chance; uncertainty" or "Something incidental to something else." Contingency as it is used here is closer to the latter definition – the dependence of events upon their initial conditions or context, which may or may not have resulted from randomness or chance. *The American Heritage College Dictionary*, 301. Furthermore, contingency represents an element of imposed necessity, implying not only elements of chance but also the constraints or "necessity" imposed by the contextual environment. Michael Shermer uses the term "contingent-necessity." Michael Shermer, "Exorcising Laplace's Demon: Chaos and Antichaos, History and Metahistory," *History and Theory* 34/1 (February 1995), 70.

define its starting point, the context that sets the process off on a given vector.[50] In other words, contingent processes are path dependent. The success of air power as a nonlinear process, then, depends not only on how it is administered, but also on the changing operational context.

The second qualitative characteristic of nonlinear processes, *interaction*, describes iterative feedback loops that continuously change the conditions upon which the process depends. Sensitivity to changes in initial conditions alone does not produce indeterminacy – interaction and variation are also required. Without complex interaction between interdependent systems, there is no chaos.[51] Nonlinear systems are typically "open" systems that exchange both energy and information with the surrounding environment.[52] In an open system, nonlinearity results both from internal iteration and from interaction and interdependence with other dynamic processes external to the system.

The classic example of the nonlinear effects of interaction is Henri Poincare's "three-body problem."[53] Although Newton's deterministic equations of motion can predict the position of a single orbiting moon around a planet, Poincare showed that they cannot accurately predict its long-term path when another moon of approximately equal size is added to the calculation. Each of the three bodies exerts forces on the other two,

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[50] Murray Gell-Mann, "The Simple and the Complex," in David S. Alberts and Thomas J. Czerwinski, eds., *Complexity, Global Politics, and National Security* (Washington D.C.: National Defense University, 1997), 17. Available at http://www.dodccrp.org/comch09.html.
[51] Uri Merry, *Coping With Uncertainty: Insights from the New Sciences of Chaos, Self-Organization, and Complexity* (Westport, CT: 1995), 29. See also Wolfram, *A New Kind of Science*, 309.
[52] The classic reference on the nature of open systems is Ludwig von Bertalanffy, *General System Theory: Foundations, Development, Applications* (New York: George Braziller, 1968).
[53] On Poincare's work, see Stewart, *Does God Play Dice?*, 49-63. See also Wolfram, *A New Kind of Science*, 313-314 and 972. On the importance of interaction, linkages, and the degree of system connectivity in the multi-body problem, see Casti, *Complexification*, 266-267.

producing nonlinear feedback and chaotic motion in the two orbiting moons.[54] In military operations, the synergy of combined arms, where the coordinated application of ground and air power is more effective than their uncoordinated use, is another example of the nonlinear effects of interaction.[55]

The popular notion of chaos is of pure randomness and disorder.[56] Strictly speaking, however, nonlinear or chaotic processes are deterministic; that is, for a closed system where initial conditions can be precisely measured and strictly controlled, a nonlinear process will give consistently repeatable results.[57] In nonlinear and chaotic processes, there may be elements of order like attractors or fractal patterns that can aid in prediction and control.[58] Using advanced computing technology and the new analytical

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[54] The reason the three-body problem is inherently unsolvable is because gravity is a nonlinear force, decreasing by the inverse square of the distance between two bodies. Sardar and Abrams, *Introducing Chaos*, 22-23.

[55] Jervis, *Systems Effects*, 40.

[56] "The term 'chaos' had been used since antiquity to describe various forms of randomness, but in the late 1970's it was specifically tied to the phenomenon of sensitive dependence on initial conditions." Wolfram, *A New Kind of Science*, 971. For an example of the term chaos used as a notion of mere disorder, see Thom Shanker, "Chaos as an Anti-U.S. Strategy," *The New York Times*, August 20, 2003. Ian Stewart argues that the overextension of the term chaos and the overemphasis on disorder and randomness have resulted in the devaluation of the idea. "Chaos has become a metaphor, but far too often, the *wrong* metaphor. Not only is the metaphor being extended to areas where there is no reason to expect a dynamical system, but the very implications of the metaphor are being misrepresented. Chaos is used as an excuse for the absence of order or control, rather than as a technique for establishing the existence of hidden order or a method for controlling a system that at first sight seems uncontrollable." Quoted in Sardar and Abrams, *Introducing Chaos*, 169.

[57] There are no agreed upon definitions for the words "random" and "deterministic." John Casti claims "...the words at random do not have an absolute, totally objective meaning." Casti, *Searching for Certainty*, 24-26. Stewart similarly writes that our definition of what is random depends heavily upon the distinction between mathematical systems where we assume perfect and infinitely precise knowledge, and reality where our knowledge is imperfect and precise. What we consider random therefore depends on the model we choose. Stewart, *Does God Play Dice?*, 280-283. Wolfram writes that something should be considered random if none of our standard methods of perception and analysis succeed in detecting any regularity in it. Wolfram, *A New Kind of Science*, 552-556. Even what appears to be a strictly random event, such as the rolling of a die, is in fact a strictly deterministic process. See J. Ford, "How Random is a Coin Toss?" *Physics Today* (April 1983), 40-47. The term random, then, does not preclude determinism – they are not exclusively opposites. Randomness is best thought of as "effective indeterminism." See also David Ruelle, *Chance and Chaos* (Princeton: Princeton University Press, 1991), 13ff.

[58] Bjorkman, et ali, "Chaos Primer," 37 and 43. On fractals and self-similarity, see Stewart, *Does God Play Dice?*, 201-227. On the subjects of "phase space" and "strange attractors," see also Gleick, *Chaos*, 119-154 and Merry, 34-40. Another example of regularity in chaotic processes is the Fiegenbaum number, a

tools of the nonlinear sciences, there may be ways to anticipate and manipulate these areas of hidden order.[59] Like other nonlinear processes, air warfare also has its attractors or repeated lessons that may be amenable to prediction and control.

Despite the historical existence of causal patterns, complex interrelationships mask the precise anchoring points for the causal chains of war, limiting our ability to predetermine the course of war.[60] The interrelated elements that define the context of air warfare include the political landscape, the technological capabilities of the competing forces, the national character of the opposing peoples, and their objectives and strategies. None of these factors can be analyzed in isolation as each is intricately related to all others. Every war is therefore unique; there are no approved solutions – each era essentially requires a new theory of war.[61]

Even where initial conditions can be well-specified, action within the operational environment changes the environment itself – objectives change with the results of combat, political will hardens or dissolves, and reacting adversaries develop new tactics and strategies through adaptation and coevolution.[62] Outcomes in war are not the result of single causes, but emerge from a confluence of factors; there is rarely clean separation

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common ratio that emerges from period-doubling cascades. Jack Cohen and Ian Stewart, *The Collapse of Chaos: Discovering Simplicity in a Complex World* (New York: Penguin Books, 1994), 228-230.

[59] Areas in which researchers have successfully managed the chaotic tendencies of systems and even exploited these areas for positive advantage include lasers, electronic circuits, chemical reactions, and electro-cardio rhythms. See William L. Ditto and Louis M. Pecora, "Mastering Chaos," *Scientific American* (August 1993), 78-84.

[60] See James J. Schneider, *The Structure of Strategic Revolution: Total War and the Roots of the Soviet State* (Novato, CA: Praesidio Press, 1994), 5-6. See also Robert Ornstein, *New World, Old Mind: Moving Toward Conscious Evolution* (New York: Doubleday, 1989), 161-165 and Cohen, "A Revolution in Warfare."

[61] As Clausewitz noted, "...every age had its own kind of war, its own limiting conditions, and its own peculiar preconceptions. Each period, therefore, would have held to its own theory of war, even if the urge had always and universally existed to work things out on scientific principles." Clausewitz, *On War*, 120 and 593. See also Eliot Cohen, *Supreme Command: Soldiers, Statesmen, and Leadership in Wartime* (New York: The Free Press, 2002), 247.

[62] Jervis, "Complex Systems," 51-65.

between either causes or effects. Although not entirely random, nonlinear processes, especially nonlinear social processes like war, are thus computationally irreducible and effectively indeterminate with the ever-looming possibility for the unintended and the unexpected.[63]

The effective indeterminacy of war increases with the passage of time, as small errors compound into major unwanted or unintended effects.[64] Interaction and feedback create higher order effects that are often delayed and not immediately apparent, further increasing uncertainty and indeterminacy. In the language of complexity theory, the possibility space for the dynamic functions of war within any given phase space increases over time.[65] Time, for example, allows the enemy to devise "asymmetric" or unexpected tactics and weapons in response to conventional strengths that complicate our reaching intended objectives.[66]

The manifestations of nonlinearity increase not only with time, but also with higher levels of aggregation and analysis. In war, the strategic whole is rarely equal to the sum of its tactical parts.[67] Local, tactical processes may be straightforward and

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[63] On the computational irreducibility of nonlinear processes, see Casti, *Searching for Certainty*, 75. On the sources of randomness and 'surprise,' see Wolfram, *A New Kind of Science*, 299 and Gell-Mann, "Fundamental Sources of Unpredictability," *Complexity* 3/1 (1997), 9-13. On the unpredictability of military processes, see Watts, *Clausewitzean Friction and Future War*, 137-144. Agent-based models, one of the analytical tools of the new sciences, confirm this uncertainty, showing that the behavior of certain complex systems is inherently unpredictable or that prediction depends upon a precise knowledge of initial conditions unavailable to the observer. Francis Fukuyama, *Our Posthuman Future: Consequences of the Biotechnology Revolution* (New York: Farrar, Straus, and Giroux, 2002), 164.
[64] Gleick, *Chaos*, 20.
[65] Bjorkman, *Air Campaign Course*, 38-39.
[66] "The pursuit of this [causal] chain, upward and downward, presents considerable problems. The greater the distance between the event and the cause that we are seeking, the larger the number of other causes that have to be considered at the same time. Their possible influence on events has to be established and allowed for, since the greater the magnitude of any event, the wider the range of forces and circumstances that affect it. When the causes for the loss of a battle have been ascertained, we shall admittedly also know some of the causes of the effects that this lost battle had upon the whole – but only some, since the final outcome will have been affected by other causes as well." Clausewitz, *On War*, 159.
[67] Eliot Cohen, "The Mystique of U.S. Air Power," *Foreign Affairs* 73/1 (January/February 1994), 119. See also Fukuyama, *Our Posthuman Future*, 164.

seemingly nonlinear. A technological device may reliably produce expected outputs for a well-measured input (a pilot enters coordinates, pushes a button, and a guided missile precisely strikes a given target), but this mechanistic precision may not govern the relationship between these "black box" technologies and their surrounding environment.[68] In the open processes of war, other influences and inputs – many either unquantifiable or the result of other indeterminate processes – come into play. Imprecise or even incorrect information may be fed into the black box. Natural phenomena like the weather, with its chaotic and uncertain dynamics, may disrupt planned actions. Social and political connections – the unpredictable, emergent behavior of humans within the system – impose further context and constraint between actions and objectives. All levels of war from bottom to top – the technical, tactical, operational, strategic, and political – interact and are interdependent, but the outcomes of war are determined only at the highest levels where the manifestations of nonlinearity are the greatest.[69]

In short, no matter how "precise" and mechanistic military technologies may become, they are but one input in the complex and chaotic dynamics of war. Nonlinearity is a part of war's underlying Clausewitzean logic. Precision technology, on the other hand, is an element of war's ever-changing grammar. In war, regardless of the levels of technological prowess of the contenders, contingency and interaction impose obstacles between planned actions and desired effects.

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[68] "Synergisms, the increased sophistication of science and technology, and the inevitable uncertainties in development processes all imply that technological outcomes and their interactions with society are certain to be complex and impossible to foresee in detail." Eugene B. Skolnikoff, *The Elusive Transformation: Science, Technology, and the Evolution of International Politics* (Princeton: Princeton University Press, 1993), 42.

[69] "The higher the ends, the greater the number of means by which they may be reached. The final aim of the war is pursued by all armies simultaneously, and we therefore have to consider the full extent of everything that has happened, or might have happened." Clausewitz, *On War*, 159. See also Edward N.

The Recomplicating Effects of Precision Warfare

Precision tactics and technologies will therefore not "linearize" air warfare; in fact, the modern "culture" of precision air power can further complicate the matter by amplifying the effects of nonlinearity in war. Although they are intricately interrelated and fundamentally irreducible, one can separate the "recomplicating" effects of the technocratic approach to warfare into three categories: 1) friction, in the narrow sense, at the technical and tactical level; 2) systemic effects, primarily at the operational level; and 3) the increasing difficulty of linking tactical precision to desired outcomes at the strategic and political levels of war.[70]

Friction in the narrow sense – "the countless minor incidents" that keep war from being a strictly linear affair – is a primary source of uncertainty at the level of application.[71] Even "foolproof" technology may not come off as advertised. As one scholar reminds us, "No military technology (indeed, no technology at all) works all the time. Inevitably, even the best-aimed laser-guided bomb will lose its fix on a target

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Luttwak, *Strategy: The Logic of War and Peace* (Cambridge, MA: The Belknap Press of Harvard University Press, 2001), 87-91; and Stewart, *Does God Play Dice?*, 292-295.

[70] The idea of the "recomplicating" effects of technology comes from Edward Tenner. Tenner suggests that technological advances often surprise us with unexpected and often deleterious qualities – "revenge effects" – that are sometime worse than the problems the technology was meant to correct. Tenner identifies five categories of "revenge effects": repeating, where a task is made easier or faster but becomes required more often; recomplicating, where the problem the technology was intended to address is actually made more difficult by the technology itself; recongesting, where an updated function becomes slower and less comfortable than the original; regenerating, where a problem seems to have been solved, but instead the solution turns out to have revived or amplified the problem; and rearranging, where a problem is delayed or physically moved, usually magnifying its effect. For a short summary see Edward Tenner, "The Real World Takes Revenge on Planners," *International Herald Tribune* (31 July 1991), 5. For a more detailed analysis see Edward Tenner, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences* (New York: Knopf, 1996). See also Charles Dunlap, "Technology: Recomplicating Moral Life for the Nation's Defenders," *Parameters* (Autumn 1999), 25. On Tenner's ideas applied to the military "system" of precision engagement, see Sakulich, "Precision Engagement and the Strategic Level of War," 30-33.

[71] Clausewitz, *On War*, 119-121. For the distinction between Clausewitzean friction in the narrow sense and a more general notion of friction, see Watts, *Clausewitzean Friction and Future War*, especially 29.

because of a passing cloud or a steering mechanism failure, and hurtle into an orphanage or hospital."[72] Even the most advanced technology requires human input and is therefore vulnerable to human error. Enemy adaptations, whether technological counter measures or changed behaviors, make the application of technology on the battlefield less mechanical than on the isolated and sterile testing ground. This is not to argue that the more sophisticated the weapons, the less likely they are to work. Technology, contrary to the claims of Luddites, is truly the engine of human progress. Nevertheless, even the most advanced military technology is not yet failsafe, especially when applied in the nonlinear environment of war. Increasing technological prowess leaves us vulnerable to the hazard of confusing improving reliability with perfection.[73]

Even if doctrinal, organizational, or technological fixes could eradicate error at the level of application of military power, there are more ominous complications less evident and harder to grasp at the systemic or operational level. New technological systems introduce greater complexity by increasing the number of components in a system and changing the nature of interactions between these components.[74] This increased systemic complexity, when combined with the increasing complexity of the surrounding environment, inspires emergent properties and behaviors that may be

[72] Eliot Cohen, "The Mystique of U.S. Air Power," 121. As one anonymous airman from WWII sardonically put it in response to a Japanese media report asking why the "barbarians" drop bombs on shrines, schools, and hospitals: "It's that lousy bomb-sight! We always miss those big factories, but hitting a tiny shrine from 27,000 ft --- that's a cinch." AFHRA file no. 248.21-2, part VI. On the issue of technological reliability, see also Azriel Lorber, *Misguided Weapons: Technological Failure and Surprise on the Battlefield* (Washington, D.C.: Brassey's, Inc., 2002).
[73] Boyd and Westenhoff, "Air Power Thinking: Request Unrestricted Climb." "Revenge effects do not mean that progress is impossible, only that in planning for it we should look more to Rube Goldberg than to Isaac Newton." Tenner, "The Real World Takes Revenge on Planners," 5.
[74] Charles Perrow, for example, warns that "network-centric" warfare will replace the "fog of war," with a "fog of systems" where seemingly innocuous errors propagate to bring down the entire system. David Hughes, "'New Orthodoxy' Under Fire: Three Critics Take Aim at Several Key Aspects of the Pentagon's Net-Centric Warfighting Doctrine,"*Aviation Week & Space Technology* (29 September 2003), 57.

impossible to predict.[75] Interdependencies or "tight couplings" between complex components may in fact make entire systems vulnerable to the cascading failures Charles Perrow calls "normal accidents."[76]

Increasing systemic complexity also generates other problems at the operational level. Precision targeting creates a demand for more and better quality information in identifying targets, determining their functional roles within the enemy system, and assessing the effects of precision attacks.[77] Those systems that gather and process information become critical capabilities requiring extraordinary protection.[78] The deluge of information these systems provide, however, is no guarantee of clarity, and may instead create an overwhelming wave of irrelevant data.[79]

As target lists grow, the demand for precision munitions to attack those targets increases, adding additional pressures on the chain of production and supply that further demand elaborate logistical and organizational support structures.[80] The more complex

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[75] See Roger Lewin, "The Right Connection," *New Scientist* 137 (February 1993), 12-13.

[76] Perrow distinguishes between "complex" and "linear" interactions within systems. Complex interactions are "those of unfamiliar sequences, or unplanned and unexpected sequences, and either not visible or not immediately comprehensible." They are characterized by branching paths, feedback loops, and jumps from one linear sequence to another. The interactive complexity of a system is most likely to lead to "system" or "normal" accidents when the components or subsystems are "tightly coupled." Tightly coupled dependencies occur where events happen fast, processes cannot be turned off, failed parts cannot be isolated from other parts and there is no "slack" in the system or other ways to keep the system's function going. Charles Perrow, *Normal Accidents: Living with High-Risk Technologies* (Princeton: Princeton University Press, 1999), 62-100.

[77] For example, see Nick Jonson, "Roche: BDAs Must Improve to Make Air Strikes More Effective," *Aerospace Daily* (18 September 2003). See also Deptula, *Effects-Based Operations*, 12 on the exponential growth of intelligence requirements during the first Gulf War.

[78] See for example Jeremy Singer, "Importance of Protecting Satellites, Grounds Systems Growing," *Space News* (15 September 2003), 26.

[79] Eliot Cohen, "The Mystique of U.S. Air Power," 113. Dennis Drew suggests that the "fog of war" may be replaced by "the blizzard of information." Dennis M. Drew, "Beware of Technology's 'Siren Song,'" *Air Force Times* (16 September 1996), 29. On the military pathologies that increased information creates, see Martin van Creveld, *Command in War* (Cambridge, MA: Harvard University Press, 1985), 258-260; and Stephen Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle* (Princeton, NJ: Princeton University Press, 2004), 64.

[80] Cohen, "The Meaning and Future of Air Power," 192. Robert R. Leonhard, *The Principles of War for the Information Age* (Novato, CA: Praesidio, 1998), 224-225.

the technological system, often the more expensive and difficult it is to employ.[81] Sophisticated precision air power technologies, like the B-2 bomber, have become the dreadnoughts of the twenty-first century – capable, yet expensive, equipment that a nation may be reluctant to risk in battle.[82] This reluctance places constraints on the flexibility and adaptability of air power tactics and strategies.[83] Combined strategies become increasingly difficult as U.S. capabilities in precision warfare far outstrip those of allies. Even if the United States was willing to universally share its high technology, few allies could afford it. By adding systemic complexity, the technologies of precision warfare (as with other technological devices applied to other social interactions) generate elements of uncertainty, necessity, and vulnerability, recomplicating the operational level of war.

A second systemic or operational effect of precision technologies is an acceleration of the dynamics of war. Compressed decision and reaction cycles, quicker information processing times, faster delivery platforms, and more accurate and lethal first strikes quicken the pace of war. The increased tempo of war may reduce exposure time to the negative impacts of nonlinearity (the goal of "hyper" warfare), but it also accelerates the rate of interaction. The acceleration of the pace of war thus increases the

[81] An exception here is the joint direct attack munition or JDAM, a global positioning system technology that can be retrofitted relatively inexpensively to existing conventional weapons. The JDAM has a procurement cost of $20,000 compared with more then $1 million per cruise missile. Michael Schrage, "Too Smart for Our Own Good," *The Washington Post* (2 June 2002), B3. The price tag of an individual JDAM, however, fails to account for the cost of the constellation of satellites needed to provide data for guidance.

[82] Andrew J. Bacevich, "Morality and High Technology," *The National Interest* 45 (Fall 1996). See also Winston S. Churchill, *The World Crisis* (New York: Charles Scribner's Sons, 1923), chapter 6. Robert Gilpin goes so far as to contend that, although the relative cost of military power may decrease thanks to the increased effectiveness of weapons, the increasing costs of military techniques contribute to the eventual economic and political decline of hegemonic societies. Robert Gilpin, *War and Change in World Politics* (Cambridge, MA: Cambridge University Press, 1981), 162.

[83] Cohen, "The Meaning and Future of Air Power," 193.

manifestations of nonlinearity, further increasing systemic complexity in the dynamics of war.

Near real-time media coverage contributes to this process, adding feedback loops that dramatically raise the costs of unintended effects (the "CNN effect").[84] The escalating rate of interaction and feedback fueled by the media increases sensitivity to initial conditions, as small errors quickly compound into major missteps.[85] Increased feedback, whether picked up on CNN or learned from the effects suffered from high-tech weapons, increases opponents' rates of adaptation, making it increasingly difficult to stay ahead in the action-reaction spiral. Although the speed and simultaneity of precision warfare – the essence of the theory of "parallel warfare" – may be intended to create complications for the enemy, it also creates the potential for dysfunction within friendly systems.[86] Less time to verify information, plan effective strategies, and adapt methods to a reacting enemy – all create greater margin for error. Modern technologies accelerate the rate of interaction in war, rapidly change environmental contexts, and increase feedback loops, magnifying the potential for unintended effects.

Linking tactical effects to desired outcomes has always been hard to do. Precision warfare, by imposing additional operational, political, and ethical considerations, arguably makes it that much harder. Picking precise points to target with guided weapons to minimize collateral effects is difficult; calculating relationships between these

[84] As General Michael Ryan noted after Operation DELIBERATE FORCE against Serbia in 1995, "One thing we know about [bomb damage assessment] is that it's going to be joint, combined, and it's going to be on CNN." Quoted in John Tirpak, "Deliberate Force," *Air Force Magazine* 80/10 (October 1997).
[85] Ron Diebert has described the world of accelerated feedback as "the hyper-media environment." Ronald J. Diebert, *Parchment, Printing and Hypermedia: Communication in World Order Transformation* (New York: Columbia University Press, 1997).
[86] Furthermore, sometimes the military may operate not only inside the decision cycle of its opponent, but also inside that of its political masters, creating additional problems in the formulation of military strategy as political decisions lag behind military operations. See Cohen, "The Mystique of Air Power," 113-115.

targets and the effects of their destruction within a target system is even more so.[87] The American tendency to, as Russell Weigley has put it, "seek refuge in technology from hard problems of strategy and policy" further complicates the problem.[88] The statistical approach to air power that measures efficiency based upon the number of airplanes and weapons required to destroy a target is an algebraic and reductionist approach to linking precision capabilities to strategic effectiveness.[89] War, however, is more than simple statistics; air strategy implies more than tallying targets.[90]

Translating precision strikes at the tactical level into desired outcomes at the strategic level is increasingly difficult in the age of precision in part because of the coevolution of ends and means in war.[91] As Clausewitz noted, "[A] change in the nature of tactics will automatically react on strategy."[92] In the highly politicized environment of modern warfare, a target's vulnerability to precision strikes and low probability of collateral damage, not military significance or strategic effect, drive the target selection process as evidenced in the air war over Kosovo in 1999.[93] At the level of national strategy, confidence in precision weapons and a sense of control over the processes of war – "achieving nicely measured political effects" – lowers the threshold of military

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[87] Cohen, "The Mystique of U.S. Air Power," 119. Cohen points out that "functional" damage (the strategic effects we seek) differs from physical damage (the tactical effects of our actions).
[88] Russell F. Weigley, *The American Way of War: A History of United States Military Policy and Strategy* (New York: MacMillan Publishing, Inc., 1973), 416. See also Cohen, "The Mystique of U.S. Air Power," 120.
[89] For an example of this statistical approach to the analysis of precision air power, see Richard P. Hallion, *Precision Guided Munitions and the New Era of Warfare*, RAAF Fairbarn, Australia: Air Power Studies Centre, 1995), 3-4. Online at http://www.fas.org/man/dod-101/sys/smart/docs/paper53.htm (accessed 17 September 2003).
[90] See Clausewitz, *On War*, 76. See also William Arkin, "Smart Bombs, Dumb Targeting?," *The Bulletin of the Atomic Scientists* (May/June 2000), 46-53.
[91] On the impossibility of separating air power as a means from its political object, see especially Bradley J. Smith, *On Politics and Airpower* (Carlsisle Barracks, PA: U.S. Army War College, 9 April 2002).
[92] Clausewitz, *On War*, 226. "But in war, as in life generally, all parts of a whole are interconnected and thus the effects produced, however small their cause, must influence all subsequent military operations and

conflict by encouraging more aggressive policies like the controversial American doctrine of military preemption.[94]

The use of precision weapons creates both expectations as well as norms concerning the bloodless conduct of war.[95] Increasingly successful discrimination in past wars, set against the notion of technological progress, places a heavy burden on the U.S. military for no-fault performances that minimize both friendly and enemy casualties.[96] Every weapon counts and disappointments carry even greater political costs.[97] Even inaccurate claims of collateral damage shape perceptions and therefore influence the conduct of military operations. For example, the frequently cited claim of up to 145,000 delayed civilian deaths resulting from the bombing of infrastructure in Baghdad in 1991 is certainly exaggerated, but nevertheless undoubtedly weighed on the minds of politicians and planners selecting targets in both Kosovo in 1999 and Iraq in 2003.[98] Air

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modify their final outcome to some degree, however slight. In the same way, every means must influence even the ultimate purpose." *Ibid.*, 158.

93 Arkin, "Smart Bombs, Dumb Targeting," 48-49.

94 Cohen, "A Revolution in Warfare," 44. Andrew Bacevich contends that the perception of precision warfare as "sanitary war" has "restored to force the political utility that it lost in the aftermath of Hiroshima," Bacevich, "Morality and High Technology." See also Charles J. Dunlap, Jr., *Technology and the 21st Century Battlefield: Recomplicating Moral Life for the Statesman and the Soldier* (Carlisle, PA: Strategic Studies Institute, 15 January 1999), 24-26; and Michael Ignatieff, *Virtual War: Kosovo and Beyond* (New York: Metropolitan Books, 2000), 179-180.

95 "In short, war, the great waster of human life, is now significantly more humane. Increasingly, war is more about destroying or incapacitating things as opposed to people. It is now about pursuing an effects-based strategy, rather than an annihilation-based strategy, a strategy that one can control an opponent without having to destroy him." Hallion, *Precision Guided Munitions and the New Era of Warfare*, 12.

96 "There are ratchets in our war experience. If we do well in the Gulf then we have to do better in our next encounter." Harvey M. Sapolsky and Jeremy Shapiro, "Casualties, Technology, and America's Future Wars," *Parameters* (Summer 1996), 123. As David Deptula notes, "The Gulf War air campaign introduced profound changes in the planning and conduct of warfare. The results were dramatic in that they changed the expectations of modern warfare. Today and in the future, armed conflict is expected to be short, decisive, and accomplished with a minimum of casualties." "Foreword" in David Deptula, *Effects-Based Operations: Change in the Nature of Warfare* (Arlington, VA: Aerospace Education Foundation, 2001), iii. See also Bacevich, "Morality and High Technology."

97 Schrage, "Too Smart for Our Own Good."

98 On the impacts of increasing casualty aversion, see Sapolsky and Shapiro, "Casualties, Technology, and America's Future Wars," 121.

power prophet Gulio Douhet's vision of limiting the brutality of war through applied technology has emerged as a morale imperative.[99]

The precision "revolution" has therefore created ambiguity about the moral legitimacy of war (*jus ad bellum*) and acceptable standards of conduct in war (*jus in bello*).[100] Should targeted assassination, made possible by more precise weapons, be an accepted method of limiting war's impact on a nation as a whole despite traditional international norms against this practice?[101] Because "smart" bombs can reduce civilian collateral damage, is there a legal and moral obligation to use them instead of less accurate (but also less expensive) "dumb" bombs?[102] Does the failure to use precision munitions demonstrate a willingness to deliberately cause civilian deaths?

The need for technical experts to manage the increasingly complex technologies of war multiplies the number of civilian contractors on or near the battlefield, erasing the clear distinction between combatant and non-combatant. As military power becomes intertwined with civilian society, discriminating between the two becomes increasingly difficult.[103] Frustrated opponents, the objects of precision warfare, frequently turn to perfidious and unconventional methods such as shielding military targets amongst civilians or using weapons of mass destruction, creating the potential for making war

[99] "Because precision is possible, it will be expected. Air warfare has thus become highly politicized. Air commanders must be extremely careful to minimize civilian casualties and collateral damage. All bombs are becoming political bombs, and air commanders must be aware of this emerging constraint." Meilinger, *10 Propositions Regarding Air Power*, 46.

[100] The most comprehensive and insightful article on the moral ambiguities created by the introduction of precision technologies is Dunlap, "Technology: Recomplicating Moral Life for the Nation's Defenders."

[101] "Current and impending technologies could permit us to reinvent warfare, once again to attack the instigators of violence and atrocity, not the representational populations who themselves have often been victimized by their leadership." Ralph Peters, "A Revolution in Military Ethics?" *Parameters* 26/2 (Summer 1996), 107. The Israelis call their controversial policy of targeted assassination of Palestinian leaders "pinpoint prevention." For a sense of the moral ambiguity this policy creates, see Greg Myre, "27 Israeli Reserve Pilots Say They Refuse to Bomb Civilians," *New York Times* (25 September 2003).

[102] See Michael Schrage, "Perfect Information and Perverse Incentives: Costs and Consequences of Transformation and Transparency," MIT Security Studies Program Working Paper (May 2003), 11.

even more, not less, destructive.[104] Rather than provide clarity, the recomplications of precision weapons have introduced additional strategic and moral ambiguity.[105]

Military Paradigms Reconsidered

Success in the new environment of war requires the right analytical paradigm.[106] To better manage military outcomes, military theories should take full account of war's nonlinear and truly chameleon-like character. Getting the analysis right requires extending the traditional scientific paradigm that has long dominated military affairs, becoming more comfortable with indeterminism and uncertainty in war, while further developing what John Casti has called "the science of surprise" to better understand the pervasive influence of nonlinear dynamics.[107]

Judged by the levels of technological, social, and material progress in Western society, the traditional scientific paradigm of determinism, reductionism, and predictability has served remarkably well. But this success may have come at a price, for the conventional mechanistic paradigm has effectively closed our eyes to the pervasive

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[103] Cohen, "The Mystique of U.S. Air Power," 128.

[104] "Unhampered by the squeamishness or scruples of our own post-Clausewitzean elites, these neo-Clausewitzeans are eager to revive old ways of employing force to subvert the status quo, adopting selected new technologies that make it possible for ever smaller groups of perpetrators to inflict ever more mayhem." Bacevich, "Morality and High Technology." See also Dunlap, "Technology: Recomplicating Moral Life for the Nation's Defenders."

[105] Cohen, "A Revolution in Warfare," 42.

[106] The term "paradigm" is used in the Kuhnian sense of "an accepted model or pattern" that not only provides the basic foundation for scientific inquiry but also determines the specific problems to be solved. Thomas S. Kuhn, *The Structure of Scientific Revolutions*. 3rd ed. (Chicago: The University of Chicago Press, 1996), 23-27. See also pp. 77-91 on "crises" within scientific paradigms as necessary preconditions for the emergence of novel theories to better explain apparent anomalies. On the importance of the social and political climate in the development of paradigms, see especially Azar Gat, *Fascist and Liberal Visions of War* (Oxford: Clarendon Press, 1998), 360.

[107] Casti, *Complexification*, ix. Acknowledging indeterminacy is not equivalent to discarding scientific approaches. "It is not 'unscientific' to expect uncertainty and accept unpredictability." Neil H. Harrison, "The Value of a Complexity Metaphor for International Political Economy," paper prepared for the 42nd Annual Convention of the International Studies Association in Chicago, February 20-24, 2001, 16. On the

irregularity, uncertainty, and unpredictability of the world around us.[108] Regularity and certainty have outweighed correctness in the design of our theoretical schemata; precision and efficiency, the products of linear logic, have frequently substituted for effectiveness.[109] The regularities observed in the past, however, may or may not apply to the present or future.[110] In an increasingly dynamic and complex world, what is needed is a complement to the traditional paradigm, an extension that widens our vantage over a world full of exceptions.[111]

Like other social scientists, Western military "scientists" have been swayed by the reductionism, mechanism, and determinism of the Laplacian paradigm in their efforts to engineer the processes of war.[112] The universal rules of Jomini and the mathematical precision of Lanchester's equations simplified and idealized combat much as Newton's

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impact of the paradigm of the Enlightenment on traditional military thinking, see Azar Gat, *The Origins of Military Thought* (Oxford: Clarendon Press, 1989).

[108] "No one feels the burden of Newton's legacy, looming forward from the past, more than the modern scientist. A worry nags at his descendants: that Newton may have been too successful; that the power of his methods gave them too much authority. His solution to celestial dynamics was so thorough and so precise- scientists cannot help but seek the same exactness everywhere." James Gleick, *Isaac Newton* (New York: Pantheon Books, 2003), 187-188.

[109] Luttwak, *Strategy*, 13. On the need for regularity and certainty in the progression of science, see Merry, *Coping With Uncertainty*, 15-20. On the confusion of precision and efficiency with effectiveness at the strategic level of war, see Sakulich, "Precision Engagement at the Strategic Level of War," 7-9.

[110] One airman writing after the First World War warned of the dangers of "formalism:" "In the long eras of peace, there is a tendency to follow blindly the forms that were found successful in the last war. Mediocre intelligence will ever seek to reduce war to rules of thumb applicable to every situation, and thus place the highest ability on an even footing with the lowest. Such efforts are of course futile." "The Influence of Airplanes on Operations in War." Anonymous lecture at the Field Officer's School, 1919, 6. AFHRA file no. 248.211-121.

[111] As Murray Gell-Mann reminds, "... the triumph of one schema over another does not necessarily mean that the loser is abandoned and forgotten." Murray Gell-Mann, *The Quark and the Jaguar: Adventures in the Simple and the Complex* (New York: W.H. Freeman and Co., 1994), 87.

[112] See Davis, *Alternate Realities*, 192. Simon Laplace was a post-Revolutionary French philosopher who liberally altered Isaac Newton's physical laws into more extreme forms of universalism and rational determinism. Laplace imagined a supreme intelligence that could "embrace in the same formula the movements of the greatest bodies in the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes." Simon Laplace, *A Philosophical Essay on Probabilities*, trans. F.W. Truscott and F.L. Emory (New York: Dover, 1951), 4 and 6. See also Gleick, *Isaac Newton*, 183-184, and Hassing, 221-225.

laws of motion idealized the complex natural world.[113] Dupuy's "Quantified Decision Model," the mechanical application of J.F.C. Fuller's principles of war in modern doctrine, and the U.S. Army's obsession with "synchronization" of military operations, are all contemporary examples of an over determined and mechanistic approach to warfare.[114] As Alan Beyerchen has correctly concluded, "We [especially those in the military] have trained our imaginations to be fundamentally linear."[115]

Scientific simplifications and the inclination toward quantification and control prevent a deeper understanding of complex, dynamic systems like war that seldom display the predictable linearity of mechanical processes.[116] Although military "scientists" have been good at describing and explaining war's linear regularities, military "artists" have been better at portraying the more messy irregularities.[117] Military

[113] See John Shy, "Jomini," in Peter Paret, *Makers of Modern Strategy* (Princeton, NJ: Princeton Universtiy Press, 1986); and F.W. Lanchester, *Aircraft in Warfare: The Dawn of the Fourth Arm* (London: Constable, 1916). Lanchester's "simplifications" include the determinism of his equations, the use of effectiveness coefficients that are constant over time, the static and homogeneous nature of the forces modeled, the lack of combat termination conditions, and his failure to account for the human factor. Andrew Ilachinski, *Land Warfare and Complexity, Part II: An Assessment of the Applicability of Nonlinear Dynamics and Complex Systems Theory to the Study of Land Warfare* (Alexandria, Virginia: Center for Naval Analysis, 1996), 65-66. See also Schneider, *The Structure of Strategic Revolution,* 12-19; Watts, *Clausewitzean Friction and Future War*, 22-23, note 31; and Lorber, *Misguided Weapons*, 12-14.

[114] Mann, "Chaos Theory and Strategic Thought," 59. See also Trevor N. Dupuy, *Numbers, Prediction and War: Using History to Evaluate Combat Factors and Predict the Outcome of Battles* (Fairfax, VA: Hero Books, 1985). On J.F.C. Fuller's legacy and the "doctrinal stability" of the principles of war, see Linda Beckerman, "The Nonlinear Dynamics of War," Science Applications International Corporation, 1999, http://www.belisarius.com/modern_business_strategy/beckerman/non_linear.htm. See also Russell W. Glenn, "No More Principles of War?" *Parameters* (Spring 1998); Bernard Brodie, "Strategy as Science," *World Politics* 1/4 (July 1949), 467-488; and Philip A. Crowl, "The Strategist's Short Catechism: Six Questions Without Answers," in Harry Borowski, ed., *The Harmon Memorial Lectures in Military History, 1959-1987* (Washington: Office of Air Force History, 1988), 377-388. On the mechanism of "synchronization," see Schmitt, "Command and (Out of) Control," 244; Watts, *Clausewitzean Friction and Future War*, 50-52; and Erik J. Dahl, "Network Centric Warfare and the Death of Operational Art," *Defence Studies* 2/1 (Spring 2002), 13. For a more optimistic interpretation of the possibilities of synchronization of complex and chaotic systems, see L.M. Pecora and T.L. Carroll, "Synchronization in Chaotic Systems," *Physical Review Letters* 64/8 (19 February 1990), 821-824.

[115] Beyerchen, "Nonlinearity and the Unpredictability of War," 200.

[116] Faber, "Competing Theories of Airpower." See also Clausewitz, *On War*, 136.

[117] For a critique of the scientific approach to war, see Bernard Brodie, "Strategic Thinkers, Planners, Decision Makers," in *War and Politics* (New York: Macmillan Publishing Co., Inc., 1973), 433-496. On the distinction between military art and military science, see especially Dennis M. Drew, *Military Art and*

affairs, writes analyst Edward Luttwak, are "pervaded by a paradoxical logic very different from the ordinary 'linear' logic by which we live in all other spheres of life." Military theory, therefore, can and should be not only quantitative and scientific, but also intuitive and creatively inspired.[118]

Those military theorists who have had the greatest staying power have recognized the importance of contingency and interaction in war. Sun Tzu, although obviously not privileged to the modern vocabulary of the nonlinear sciences, nevertheless demonstrated an appreciation for the nonlinear nature of war in his classic *The Art of War*.[119] Written against the background of one of the most chaotic periods in China's history, *The Art of War* is a practical manual for achieving disproportionately positive effects in war.[120] Sun Tzu's goal of subduing the enemy without fighting is nonlinearity taken to its extreme.[121] Recognizing the uniqueness of each situation, Sun Tzu wrote: "I do not repeat my tactics but respond to circumstances in an infinite variety of ways."[122] His water metaphor further emphasized the role of contingency and the need for adaptation: "And as water has no constant form, there are in war no constant conditions."[123] Sun Tzu's discussion of the relationship between the normal (cheng) and extraordinary (ch'i) forces in war and his recommendation to first attack the enemy's strategy, not his armed forces, reflect the importance of interaction, interdependence, and coevolution in war. Although at times falling back on the "scientific" approach to war and the possibilities for forecasting

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the American Tradition: The Vietnam Paradox Revisited, Report No. AU-ARI-CP-85-3 (Maxwell AFB, AL: Center for Aerospace Doctrine, Research, and Education, April 1985). Clausewitz contended that war was neither art nor science, but rather an act of human intercourse, "... a kind of commerce on a larger scale." Clausewitz, *On War*, 149.

118 Luttwak, *Strategy*, 2.

119 Ilachinski, *Land Warfare and Complexity, Part II*, 47.

120 Sun Tzu, *The Art of War*, Samuel B. Griffith, trans. (Oxford: Oxford University Press, 1971), 21.

121 "To subdue the enemy without fighting is the acme of skill." *Ibid.*, 77.

122 Sun Tzu, *The Art of War*, 100.

victory through quantitative analysis, Sun Tzu's *The Art of War* is suffuse with analogies that reveal an informed understanding of the nonlinear nature of war.[124]

In a seminal article published in 1992, Alan Beyerchen contended that Prussian military theorist Carl von Clausewitz had an even deeper grasp of the nonlinear nature of war than did Sun Tzu.[125] For Clausewitz, war was a duel between two living forces, a *zweikampf* or "struggle of twos," and therefore never an isolated act.[126] Every war was "rich in unique episodes," where ends and means interact and "true causes may be quite unknown."[127] His "paradoxical trinity" – the balance between blind natural force, chance, and rational policy in which war was "like an object suspended between three magnets" – is a near perfect analogical fit with Poincare's later work on the indeterminacy of the three-body problem.[128] Although military action should run like a wound up clock, "the very nature of interaction is bound to make it unpredictable."[129]

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[123] Sun Tzu, *The Art of War*, 101.

[124] For quantitative analysis and prediction in *The Art of War*, see *ibid.*, 71 ("With many calculations,one can win; with few one cannot.") and 82-88 (the five circumstances in which victory can be predicted). One passage in particular seems to show Sun Tzu's recognition of the coexistence of order and disorder on the battlefield: "In the tumult and uproar the battle seems chaotic, but there is no disorder… Apparent confusion is a product of good order…" *Ibid.*, 92.

[125] Beyerchen, "Nonlinearity and the Unpredictability of War." Bernard Brodie, writing twenty years before Beyerchen's influential article, also noted Clausewitz' grasp of the complex, chaotic, and inherently indeterminate nature of war. Bernard Brodie, *War and Politics*, 440-453. Andrew Ilachinski contends that the "intuition" that Clausewitz deemed necessary for success as a military commander is nothing less than the ability to perceive patterns in a seemingly patternless process. Ilachinski, *Land Warfare and Complexity, Part II*, 27 and 112. See also Christopher Bassford, *Clausewitz in English: The Reception of Clausewitz in Britain and America, 1815-1945* (New York: Oxford University Press, 1994), 25-27 and 217-18.

[126] "The very nature of interaction is bound to make it unpredictable." Clausewitz, *On War*, 139. See also Alan D. Beyerchen, "Nonlinearity and the Unpredictability of War," in Czerwinski, *Coping With the Bounds*, 171-172. See also Ilachinski, *Land Warfare and Complexity, Part II*, 171.

[127] "The deduction of effect from cause is often blocked by some insuperable extrinsic obstacle: the true causes may be quite unknown. Nowhere in life is this so common as in war, where the facts are seldom fully known and the underlying motives even less so." Furthermore, "…effects in war seldom result from a single cause; there are usually several concurrent causes." Clausewitz, *On War*, 120 and 156-157.

[128] Beyerchen, "Nonlinearity and the Unpredictability of War," 174-175. Clausewitz, *On War*, 89. Clausewitz was himself an amateur scientist, explaining his fascination for scientific metaphors like centers of gravity, friction, and bodies suspended between magnets. Schmitt, "Command and (Out of) Control," 221.

[129] Clausewitz, *On War*, 139 and 216.

Since combat occurs in such a characteristically irregular environment, the true role of military theory for Clausewitz is *understanding*, and not *prediction.*[130] The utility of Clausewitz's understanding went beyond the purely theoretical. As a "champion of disproportionate effects and unpredictability," Clausewitz (argued Beyerchen) deliberately explored the concept of nonlinearity to give the Prussian underdogs one up against the stronger French, "to understand and use against the French their linearizing blindspots."[131]

With the growing awareness of the pervasiveness of nonlinearity in the natural world, the natural sciences have shifted toward a new paradigm centered on the nonlinear studies of chaos and complex systems. These "new sciences," linking a number of disciplines ranging from chemistry, thermodynamics, and physics to anthropology, biology, and sociology, are more theoretically robust than the traditional scientific paradigm for an inherently irregular and disorderly world.[132] The science of chaos is the study of dynamical systems whose outputs are sensitive to changes in initial conditions and that evolve in time according to nonlinear rules.[133] Complex systems theory refers to the study of systems composed of many interacting parts.[134] The common element of

[130] "Theory cannot equip the mind with formulas for solving problems, nor can it mark the narrow path on which the sole solution is supposed to lie by planting a hedge of principles of either side. But it can give the mind insight into the great mass of phenomena and of their relationships, then leave it free to rise into the higher realms of action." Clausewitz, *On War*, 578. For a more contemporary analysis of the role of military theory, see Rosenau, "Many Damn Things Simultaneously," 92.
[131] Beyerchen, "Nonlinearity and Unpredictability in War," 167.
[132] Schmitt, "Command and (Out of) Control, 227-228. The following taxonomy of the new sciences is taken from Ilachinski, *Land Warfare and Complexity, Part II*, 17-18. See also Fukuyama, *Our Posthuman Future*, 162-166.
[133] For a concise discussion of the development of chaos theory, see Wolfram, *A New Kind of Science*, 971. The best popular account is James Gleick's *Chaos: The Making of a New Science*. Ian Stewart's *Does God Play Dice? The New Mathematics of Chaos* offers the most accessible mathematical explanation of chaos for the non-mathematician. See also Jensen, "Classical Chaos."
[134] For a concise history of complexity theory, see Wolfram, *A New Kind of Science*, 861-863. On the evolving definition of what is complex, see *ibid.*, 1068-1069. The best popular account of development of complexity theory is in M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and*

both chaos and complexity is nonlinearity – the disparity between input and effect.[135] By accounting for nonlinearity in the surrounding world, the new sciences of chaos and complexity, or "chaotics," address indeterminacy, irregularity, and anomaly better than the traditional paradigm of universal order.[136]

Just as the appeal of the deterministic paradigm resulted in its extension beyond the natural sciences, the utility of the new nonlinear paradigm has led to its acceptance by other disciplines.[137] Scholars have applied the nonlinear paradigm to a wide range of subjects including international political economy, history, business and management, the operation of the stock market, cardiology, and even the field of personal development and self-help.[138] Almost two centuries after Clausewitz first wrestled with the nonlinear nature of war, modern military theorists are also now turning to chaos and complexity studies for metaphors for understanding and, increasingly, for practical solutions in

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Chaos (New York: Simon and Schuster, 1992). For a more technical, yet accessible account, see Gregoire Nicolis and Ilya Prigogine, *Exploring Complexity: An Introduction* (New York: W.H. Freeman and Company, 1989). As Ilachinski points out, complexity theory is in some ways a misnomer because the object of study is really the *simplicity* of relationships that underlies complex structures. Ilachinski, *Land Warfare and Complexity, Part II*, 20.

[135] "It is no coincidence that complexity and chaos are related. Both are part and parcel of the theory of nonlinear dynamics, one of *the* great success stories of late 20th century science. As soon as you permit the flexibility of nonlinearity in your models of nature, you will encounter these two phenomena. And if you don't permit that flexibility – well, you're a pachydermologist operating in a world that you think consists solely of large grey creatures with big floppy ears, but which actually contains beasts that you haven't even dreamed of. Ignorance may be bliss, but it's bliss purchased at a price that's not worth playing." Stewart, *Does God Play Dice?*, 367.

[136] Although there is no agreed upon name for the still-emerging scientific paradigm of nonlinearity, three European scholars suggest the term "chaotics" to replace the overly broad and eventually outmoded name "new sciences." George Anderia, Anthony Dunning and Simon Forge, *Chaotics* (Twickenham, UK: Adamtine Press, 1997). On the staying power of the new sciences paradigm, see Ziauddin Sardar and Jerome R. Ravetz, "Complexity: Fad or Future?" *Futures* 26/2 (July-August 1994): 563-567.

[137] Harold Morowitz, "Metaphysics, Metaphor, Meta-Metaphor, and Magic," *Complexity* 3/4 (1998), 19-20.

[138] Bjorkman, *Air Campaign Planning Course*, 60-66. Some specific examples of the application of the new paradigm include Harrison, "The Value of a Complexity Metaphor for International Political Economy"; Roger Beaumont, *War, Chaos and History* (Westport, CN: Praeger, 1994); Jim Jubak, "Can Chaos Beat the Market?" *Worth* (March 1993) and E. Peters, *Chaos and Order in the Capital Markets* (New York: Wiley, 1991); Robert May, "The Chaotic Rhythms of Life," *New Scientist* 124 (November 1989), 37-41 and A. Garfunkel and M.L. Spano, "Controlling Cardiac Chaos," Science 257 (28 August 1992), 1230-1235; David H. Freedman, "Is Management Still a Science?" *Harvard Business Review* 70,

command and control, decision-making, battlefield organization, simulation and modeling, and even aerial targeting.[139] This shift, however, is still ongoing and incomplete; its ultimate realization requires repeated affirmations of the applicability of the nonlinear model to the military realm.

Contemporary U.S. military doctrine, the crystallization of current military theory, is hesitantly incorporating elements of the new scientific paradigm. The United States' Marine Corps has been the most ambitious of the services in adopting the new viewpoints. Following General Paul Van Riper's guidance, the 1997 versions of Marine Corps' Doctrinal Pamphlets (MCDPs) make frequent use of concepts taken from the study of chaos and complexity.[140] Army doctrine lags furthest behind, still built largely on linear and mechanical Newtonian concepts such as synchronization – "arranging activities in time, space, and purpose to mass maximum relative combat power at a

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26-38; and John Briggs and F. David Peat, *Seven Life Lessons of Chaos: Timeless Wisdom from the Science of Change* (New York: HarperCollins Publishers, 1999).

[139] Shermer, "Exorcising Laplace's Demon," 62-63. For an early attempt to apply the nonlinear sciences to the study of war, see Alvin M. Saperstein, "Chaos – A Model for the Outbreak of War," *Nature* 309 (1984), 303-305 (see also his later article "War and Chaos," *American Scientist* (November-December 1995), 548-557). For applications to practical military problems, see Schmitt "Command and (Out Of) Control, 219-246; John A. Koenig, *A Commander's Telescope for the 21st Century: Command and Nonlinear Science in Future War* (Quantico, VA: Marine Corps Command and Staff College, 22 April 1996); Antulio J. Echevarria, "Optimizing Chaos on the Nonlinear Battlefield," *Military Review* (September-October 1997), 26-31; James A. Dewar, James J. Gillogly and Mario L. Juncosa, *Non-Monotonicity, Chaos, and Combat Models* (RAND Corporation, R-3995-RC, 1991); and Robert W. Freniere, John Q. Dickmann, and Jeffrey R. Cares, "Complexity-Based Targeting: New Sciences Provide Effects," *Air and Space Power Journal* (Spring 2003). On the application of complexity theory to management of the military bureaucracy, see Eric B. Dent and Cameron G. Holt, "CAS in War, Bureaucratic Machine in Peace: The U.S. Air Force Example," *Emergence* 3/3 (2001), 90-107.

[140] In *MCDP 1, Warfighting*, discussions of complexity and nonlinearity appear on pp. 8, 12-13, and 45. In *MCDP 1-1, Strategy*, see 16-20. In *MCDP 6, Command and Control*, see 44-47. Christopher Bassford, "Doctrinal Complexity in Marine Corps Doctrine," in F.G. Hoffman and Gary Horne, eds., *Maneuver Warfare Science* (Quantico,VA: United States Marine Corps Combat Development Command, 1998). See also Williamson Murray, "Military Culture Does Matter," *Foreign Policy Research Institute WIRE* 7/2 (January 1999).

decisive place and time" – and a continuing devotion to the traditional principles of war.[141]

Air Force published doctrine is somewhat less mechanical and more attuned to the Clausewitzean fog of war.[142] Acknowledging that "the complexity of war in general and the unique character of each war in particular" precludes the use of principles as a checklist for victory, Air Force doctrine goes on to list the traditional principles nonetheless, recommending them as "valuable guides to evaluate potential courses of action."[143] The military services' joint doctrinal vision of future war, *Joint Vision 2020*, also notes the inherent complexity of joint operations in war and the ubiquity of uncertainty and chance.[144] While its authors claim "the fundamental sources of friction cannot be eliminated," *Joint Vision 2020* nevertheless promotes the possibilities of full knowledge and control (e.g.,"full spectrum dominance – the ability of U.S. forces ... to defeat any adversary and control any situation across the full range of military operations").[145] Although the nonlinear paradigm has established a cautious toehold in

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[141] *Field Manual, 3-0: Operations* (Washington, D.C.: Headquarters, Department of the Army, 14 June 2001). See especially chapter 4: "Fundamentals of Full Spectrum Operations."

[142] "Despite technological advances and the best of plans and intentions, war will never be as straightforward in execution as we planned, nor free of unintended consequences. ...War is a complex and chaotic endeavor." *Air Force Doctrine Document 1: Basic Doctrine* (Washington, D.C.: Headquarters United States Air Force, 17 November 2003), 14-15. Two Air Force officers assessing their service's acceptance of the new paradigm argue that the Air Force has successfully adopted the paradigm for warfighting, but the shift is still incomplete in peacetime organizational structures. Dent and Holt, "CAS in War, Beaucratic Machine in Peace."

[143] *Air Force Doctrine Document 1*, 20.

[144] *Joint Vision 2020*'s discussion of innovation also shows elements of the new nonlinear paradigm, stressing the importance of interaction and the persistence of uncertainty in the innovation process. *Joint Vision 2020: America's Military Preparing for Tomorrow* (Washington DC: Government Printing Office, June 2000), 10-11.

[145] *Joint Vision 2020*, 6. See also Beyerchen, "Nonlinearity and the Unpredictability of War," 184-187. *Joint Vision 2020* further confirms the persistence of indeterminacy in war: "...information superiority neither equates to perfect information, nor does it mean the elimination of the fog of war." *Joint Vision 2020*, 12. See also Beyerchen, "Nonlinearity and the Unpredictability of War," 184-187. For a critique of the concept of information dominance which first appeared in *Joint Vision 2010* (the predecessor to *Joint Vision 2020*), see John Schmitt and G.A. Klein, "Fighting in the Fog: Dealing With Battlefield Uncertainty," *Marine Corps Gazette* (August 1996).

military doctrine, the traditional paradigm of determinism and mechanistic control has yet to be driven from the theoretical high ground.

Joint Vision 2020 suggests that nonlinearity in war – the indeterminacy, uncertainty, and unintended consequences – is more than just something to be understood and suffered through. By creating a "frictional imbalance," the negative manifestations of nonlinearity can also be inflicted on an opponent. Clouding the enemy's knowledge of initial and subsequent conditions through deception or accelerating the pace of war beyond an opponent's ability to react ("getting inside the enemy's decision cycle") are two ways of imposing this frictional imbalance.[146] An awareness of nonlinearity in war may therefore go beyond mere understanding to provide practical benefit on the battlefield.[147]

If imposing friction on an enemy can be thought of as imposing negative nonlinearity, there is also a positive side to the military application of nonlinearity. Military strategists have long sought disproportionately positive effects, like the fall of Achilles to a single arrow from the quiver of Paris.[148] Attacking enemy "decisive points" or "centers of gravity" to achieve disproportionate outcomes with minimal inputs is the

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[146] *Joint Vision 2020*, 6. The notion of a "balance of friction" originated with Barry Watts in his insightful paper, *Clausewitzean Friction and Future War.* Getting inside the decision cycle of the enemy is the essence of John Boyd's OODA loop. See John R. Boyd, "A Discourse on Winning and Losing," (unpublished briefing and essays) (Maxwell AFB, AL: Air University Library, Document No. MU 43947, August 1987).
[147] For a discussion of possible applications of nonlinearity to the battlefield, see Bjorkman, *Air Campaign Planning Course*, 34-72.
[148] Robert Jervis similarly distinguishes between the positive and negative impacts of nonlinearity, using the labels "desired unintended consequences" and "undesired unintended consequences" (although he has in mind more restrictive categories that include only *unintended* effects). Jervis, *Systems Effects*, 65-66. Sir Basil Liddell-Hart's "strategy of the indirect approach" is a classic example of deliberately using the nonlinearity of war to one's advantage. See his book *Paris: Or the Future of War* (New York: Dutton, 1925) for an early expression of this idea and Liddell-Hart's *Strategy* (London: Faber and Faber, Ltd., 1967) for a more fully developed and supported explanation.

classic military method of achieving positively nonlinear effects.[149] Although war's nonlinear nature makes direct control over ultimate outcomes difficult, military strategists can nevertheless take advantage of both negative (inflicting uncertainty on an opponent) and positive (purposely seeking disproportionate effects) manifestations of nonlinearity to indirectly influence the outcomes of war.

Modern air power, given its speed, range, stealth, and potential for surgical precision, is a particularly effective means for imposing disproportional results, for achieving the kind of cascading effects foretold by early air power theorists, where a strike against a single vital component brings an entire system to its knees.[150] From the beginning, air power proponents have advocated the "strategic" potential of air power – where small air power inputs (dropping bombs) can potentially have major consequences (strategic effects).[151] Air power, with its ability to overfly enemy defenses to strike directly at the sources of enemy power, is a fitting tool for imposing positive nonlinearities on opponents.

Air power, no matter how accurate and precise, is perhaps the most difficult of military forces to measure and precisely quantify. "[Air war] involves hundreds, if not thousands of aircraft," write Williamson Murray and Robert Scales in their history of the recent war in Iraq. "The incidents and battles occur at blinding speed. There are no clear markers to indicate exactly what happened except perhaps the number of aircraft lost. Effects are equally hard to evaluate, especially during a conflict in progress. Damage to

[149] See Joe Strange, *Centers of Gravity and Critical Vulnerabilities: Building of the Clausewitzean Foundation So That We Can All Speak the Same Language* (Quantico, VA: Marine Corps University Foundation, 1996).
[150] Deliberately seeking disproportionate effects is the essence of "industrial web strategy" of the Air Corps Tactical School in the interwar period and the "cascading effects" of modern air power theorists discussed in subsequent chapters.

ground targets by bombs or strafing may appear to be massive, when in fact it has little impact on the enemy's ability to fight. At other times the destruction from air attacks may be devastating, but no reliable way exists to measure damage until the conflict is over."[152] Assessment, despite great effort in collecting and documenting the evidence, remains an intractable problem even in the era of satellite imagery and unmanned aerial vehicles, especially since photographic evidence says little about the most important impacts of bombing, the psychological effects. Measuring the effectiveness of air power is necessarily as much about qualities as it is about quantities.[153]

Put simply, *air power is an inherently nonlinear force*. Control over the outcomes of air warfare, therefore, demands more than *quantitative* precision. Control demands a better *qualitative* understanding of the pervasive role of nonlinearity in war. Because it better fits both the nature of the instrument, as well as the environment of application, the nonlinear scientific paradigm is a better guide for the analysis of precision air power than traditional deterministic approaches.

Method and Organization

This study is a necessarily selective examination of the consequence of nonlinearity in the history of American precision air power. In the place of "rigorous" *quantitative* analysis, this study focuses on the *qualitative* aspects of nonlinearity and

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[151] "Air power changed things by compressing the line between the strategic and tactical effects. Aircraft can routinely conduct operations that achieve strategic level effects." Meilinger, *10 Propositions*, 10-11.
[152] Williamson Murray and Robert H. Scales, *The Iraq War: A Military History* (Cambridge, MA: The Belknap Press of Harvard University Press, 2003), 156.
[153] On the intangibles of air power, see also Williamson Murray, "Strategic Bombing: The British, American, and German Experiences," in Williamson Murray and Allan R. Millett, eds., *Military Innovation in the Interwar Period* (New York: Cambridge University Press, 1996), 98-99. On the shortcomings of the quantitative approach to air power, see Sherry, *The Rise of American Air Power*, 232-233.

precision air power.[154] Although quantitative statistics on bombing accuracy, numbers of airplanes employed, bomb tonnages dropped, and the count of unintended civilian casualties are useful, their ultimate utility is in building and reinforcing an understanding of contingency and interaction in war, not in computing neat regression lines to generate predictions for future application.[155] The quest for the "holy grail" of precise causal linkages between action and ultimate effect might not only be futile, but also potentially harmful. If fixation on analytical precision and the material aspects of warfare restricts our flexibility and adaptability in the employment of air power, this fixation is not only setting us up for frustration, but also quite possibly paving the way for a major failure or "system accident." Successful adaptation to the ever-changing and increasingly complex environment of war requires the removal of our linear blinders.

Although more than fifteen years have passed since the first applications of the new sciences paradigm to military studies, scholars are still struggling with ways to apply this paradigm. The methodologies of the new sciences are still immature, having ill-defined boundaries and concepts, and require both patience and creativity in their application.[156] Since there are as many ways of going about the new sciences as there are new scientists, the real analytical challenge lies in determining the correct level of application of the yet-emerging paradigm. Social scientists may be anxious for the new

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[154] In the vocabulary of the social sciences, this study is more *ideographic* than *nomothetic*, addressing a historical phenomenon inadequately or wrongly accounted for and then developing a better "synoptic" judgment about this phenomenon. See Paul W. Schroeder, "History and International Relations Theory: Not Use or Abuse, but Fit and Misfit," *International Security* 22/1 (Summer 1997), 68. See also Jack S. Levy, "Too Important to Leave to the Other: History and Political Science in the Study of International Relations," *International Security* 22/1 (Summer 1997), 22-33.

[155] In the words of Alan Beyerchen, "...seeking exact analytical solutions does not fit the problems posed by war." Beyerchen, "Nonlinearity and the Unpredictability of War," 165.

[156] Andrew Ilachinski gives six general guidelines to assist in the transition: 1) develop "nonlinear intuition; 2) look for inherent nonlinearities in conventional models; 3) emphasize strong interdisciplinarity' 4) redefine traditional measures of effectiveness along the lines of the new sciences; 5) don't shy away from

paradigm to meet their expectations of "scientific" analysis. The level of metaphor and analogy, however, seems more appropriate at the present time than formal modeling.[157] The most useful role for the nonlinear paradigm given its state of development is, borrowing the words of Clausewitz, "to provide a thinking man with a frame of reference ... rather than to serve as a guide which at the moment of action lays down precisely the path he must take."[158]

Andrew Ilachinski suggests several tiers of applicability of complex systems theory to combat, ranging from the use of general metaphors of complexity to the development of fundamentally new conceptualizations of combat for actual application on the battlefield. This study applies the lower tiers of Ilachinski's taxonomy, seeking to enhance conceptual links between complexity and warfare, to apply the basic principles and metaphors of complexity theory, and to describe real-world combat from a nonlinear perspective.[159] Metaphor-based approaches, although frequently criticized, are the essence of scientific understanding – academics from Newton to Einstein have made elaborate use of metaphor and analogy to clarify and communicate their intellectual

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"simple" models that underlie more complex reality; and 6) attack problems from diverse fronts. Ilachinski, *Land Warfare and Complexity, Part II*, 9-10.

[157] David Ruelle similarly notes that "...the impact of chaos remains for the time being at the level of scientific philosophy rather than quantitative science." Ruelle, *Chance and Chaos*, 79. Ilachinski argues that for a model to accurately depict the complexities of land combat, it may have to be just as physically complex as land combat itself. The only perfect model of a complex system is the system itself. Ilachinski, *Land Warfare and Complexity, Part II*, 24 and 37-38. See also Linda Beckerman, "Is the Time for Revolution Upon Us?" http://www.sisostds.org/webletter/siso/iss_51/art_236.htm (accessed 6 Jul 03).

[158] Clausewitz, *On War*, 89. As John Holland emphasizes, despite our hopes for a theoretical panacea, complexity theory is "meant for thought experiments rather than for emulation of real systems." John H. Holland, *Hidden Order: How Adaptation Builds Complexity* (Reading, MA: Addison-Wesley Publishing Co., 1995), 98.

[159] Ilachinski, *Land Warfare and Complexity, Part II*, 40-43. Illachinski's formal applications of complexity theory to land warfare include autonomous robotic devices, agent based models, and data mining and pattern recognition for the development of universal laws of combat.

discoveries.[160] Using the new sciences as a "deep metaphor" will reintroduce and highlight nonlinear relationships previously simplified to make them amenable with traditional scientific methods.[161] In this way, the nonlinear paradigm might give new viewpoints over the history of precision air power, perhaps even creating a new perception of past events and present realities.[162] Building conceptual metaphors is the first step, but certainly not the last, in the application of the nonlinear paradigm to military studies.

A topic as complex as air warfare deserves a multidisciplinary approach, but one that is primarily rooted in historical study. As William McNeill has pointed out, history can serve a model for the other disciplines as they wrestle with the application of the new worldview in that "it deals with the most complex levels of reality we are aware of, that is, the world of agreed-upon meanings that guides our interaction with one another and with the biological, chemical, and physical worlds around us."[163] History takes full account of "the arrow of time" or the irreversibility of the interactions of air warfare, recognizing the contingent nature of past, present, and future events. The inferential and descriptive outlook of history, viewed through the lens of a nonlinear metaphor, is most

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[160] Clausewitz himself criticized the unthinking use of jargon and metaphors as "nothing more than ornamental flourishes of the critical narrative." Clausewitz, *On War*, 168-169. Relying on "metaphors to buttress the logic of their arguments" is one of Peter Faber's pathologies of air power theory. Faber's point, on deeper examination, is not that the use of metaphor is wrong, only that previous metaphors have failed to account for armed conflict as a "nonlinear, interactive process bedeviled by feedback loops, delays, 'trigger effects,' and qualitative changes." Faber, "Competing Theories of Airpower."

[161] Alan D. Beyerchen, "Clausewitz, Non-linearity, and the Importance of Imagery," in David S. Alberts and Thomas J. Czerwinski, eds., *Complexity, Global Politics, and National System* (Washington D.C.: National Defense University, 1997) On the different levels of metaphor and their value to scientific inquiry, see Illachinski, 44-46, and Czerwinski, *Coping With the Bounds*, 69ff.

[162] "... if, in the end, it turns out that complex systems theory provides no generally new insights into war *other than to furnish a rich scaffolding of provocative and suggestive metaphors* around which an entirely new view of warfare can be woven... complex systems theory will have nonetheless fulfilled an enormously important function." [italics in original] Ilachinski, *Land Warfare and Complexity, Part II*, 48.

[163] William H. McNeill, "History and the Scientific Worldview," *History and Theory* 37/1 (Feb. 1998), 1.

appropriate for a world that stubbornly resists the mathematical predictability of the hard scientist.

The historical analysis of American precision air power that follows looks at three interdependent areas – the development of the technological means to put bombs on target, the origins and evolution of the ideas behind employing these means, and the impact of the experience of war on both the theory and technology of precision air power. Chapter two examines the intellectual and technological origins of American precision air power between the two World Wars. This chapter shows the influence of the American experience in World War I, interservice rivalry following the war, and the social, political, and economic context of the 1920's and 1930's on the development of the first *schema* (in the language of the new sciences, the internal model that guides the actions of a complex system) for applying air power in discrete ways to achieve more expansive results. It was from this complex mix of influences that early American air theorists fashioned the linear view of air power as an engineering problem, a view manifest in the doctrine of High Altitude Precision Daylight Bombing that became the basis for air planning in World War II.

The third chapter focuses on the case of Allied air attacks against German lines of communication before the Normandy invasion. The development of American precision air power has followed a process of "punctuated equilibrium" rather than consistent historical progress and it is during times of war that change in the ways and means of air power accelerates most rapidly.[164] The case of the 1944 Transportation Plan is

[164] On the concept of "punctuated equilibrium" in the natural sciences, see Stephen J. Gould, "Punctuated Equilibrium in Fact and Theory," in S. Somit and S.A. Peterson, eds., *The Dynamics of Evolution: The Punctuated Equilibrium Debate in the Natural and Social Sciences* (Ithaca, NY: Cornell University Press, 1992), 54-84.

representative of the adaptations required to make the theoretical ideal of precision air power more effective in the less than ideal environment of war. The experience clearly demonstrates not only the nonlinear nature of air warfare, but also the impacts of this nonlinearity on the planning, execution, and post-operational assessment of air power's effects.

Chapter four traces the evolution of precision air power after World War II through the early Cold War, highlighting lessons learned from the experience of war and the scientific influences that dominated the post-World War II Air Force. Building on the success of analytical methods like operations research, American analysts turned to the rationality of quantitative methods and the efficiency of science to improve air power's contributions toward national political objectives. But as the nuclear stalemate and the conventional war in Korea demonstrated, the political effects of air power steadfastly resisted control through scientific analysis and manipulation. The chapter also discusses the pursuit of new precision technologies and the influence of increasing technological complexity on American views of air power.

The emergence of effective precision weapons in Vietnam is the subject of chapter five. The United States Air Force had written off the untidy air war in Korea as an anomaly; the experience in Vietnam confirmed, however, that irregularity and incongruity between theory and practice was a repetitive lesson of air warfare. After the early disappointments of the ROLLING THUNDER bombing campaign, air power adaptations (as in Normandy in World War II) and the introduction of effective precision air-to-ground weapons led to the qualified successes of the 1972-73 LINEBACKER campaigns. More precise air power did make a positive contribution toward this end.

Precision air power did not, however, as American airmen's unitary explanation of its effectiveness might lead one to believe, solely and definitively shape the outcome of the Vietnam War. Nascent air power technologies were but one among many in the complex mix of causes that contributed to success.

Chapter six looks at the race between theory and technology in the post-Vietnam era and the spoils of that race – the truly revolutionary role of precision air power in Operation DESERT STORM. During DESERT STORM airmen combined effective precision weapons with well-developed operational concepts that were the byproduct of the lively debate over military reform in the late 1970's and 1980's. In the midst of this over-determined success, however, there were further indications of the relentlessly nonlinear nature of war and the limits to mastery of the strategic effects of air power. Post-war theorists like John Warden and David Deptula sought to overcome these limits, in part by introducing elements of the nonlinear paradigm to their theories to better account for the inherent uncertainty and the indeterminate nature of air warfare.

Precision air power had succeeded in DESERT STORM to a certain extent because of the fortuitous situation in which it was applied. The seventh chapter discusses the air campaign against Serbia in 1999 as a less fortuitous case where airmen armed with mature theories for the use of precision weapons and operationally effective precision technologies nevertheless achieved less than decisive results. Misplaced confidence in precision weapons after DESERT STORM led airmen in ALLIED FORCE to embrace a deterministic mindset that manifested itself in the mechanical servicing of target lists. As in World War II and Vietnam, meeting the imprecise and ever-shifting political conditions of the war required the flexible adaptation of air power to achieve desired outcomes. Having presented the nonlinearity of the precision air war over Kosovo, the final chapter then offers some summary conclusions and guideposts for the future of American air power.

As Colin Gray rightly warns, there is a danger of "overexplanation" in applying the metaphor of chaos and complexity to the study of war. Although war may be a chancy affair, victory still goes to the more competent battalions; strategy works, even if sometimes in unforeseen ways. Although this study may be quick to point out where our ideas and technologies have gone astray, this is not to imply that they have always done so. Technical competence and the inclination to exploit technology for strategic advantage, while sometimes creating potential vulnerabilities, has also been one of the American military's greatest strengths.[165] That said, there is still value in overexplanation, if only to remind us that war, as a complex interaction between human societies, will always hold its fair share of the unexpected. Surprise may be less debilitating when expected in advance.[166]

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[165] Gray, *Weapons for Strategic Effects*, 29-30.

[166] See especially Colin S. Gray, *Transformation and Strategic Surprise* (Carlisle, PA: Strategic Studies Institute, April 2004), 9-13.

The Origins of Precision Air Power

And in the air are no streets, no channels, no point where one can say of an antagonist, "If he wants to reach my capital he must come by here." In the air all directions lead everywhere.

H. G. Wells, *War in the Air*[1]

From the very beginning, Americans thought of airpower in nonlinear ways. By leaping over the enemy's front-line forces, airplanes could strike deep against supply depots, industrial concentrations, or even population centers. By attacking the sources rather than the manifestations of an enemy's strength, a relatively small and cost-effective air input could cause a disproportionately large outcome – an opponent's physical and/or moral collapse. Air power, what General "Billy" Mitchell called "the ability to do something from the air," could be an independent force, both necessary and sufficient for achieving national strategic objectives.[2] The American doctrine of high-altitude precision daylight bombing that emerged before World War II was "predicated on the basic fact that...heavy bombers can fly deep into heavily-defended enemy territory, drop an effective load of bombs on a target with pin-point precision, and return to base without losses disproportionate to the damage done to the enemy."[3]

High-altitude precision daylight bombing was the evolutionary ancestor of modern American visions of air power. The methods this doctrine prescribed and the

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[1] H.G. Wells, *War in the Air* (1908), Chapter 8, Section 1. Available at http://www.online-literature.com/wellshg/warinair/ (accessed 3 November 2004). For a discussion of Wells' view of early air power, see Michael Sherry, *The Rise of American Air Power: The Creation of Armageddon* (New Haven, CT: Yale University Press, 1987), 8-9.
[2] General William "Billy" Mitchell quoted in Charles M. Westenhoff, ed., *Military Air Power: The CADRE Digest of Air Power Opinions and Thoughts* (Maxwell AFB, AL: Air University Press, 1990), 18. On the sufficiency of air power, see Laurence Kuter, "An Inquiry into the Subject of 'War'," ACTS Lecture, 1935. Air Force Historical Research Agency, Maxwell AFB, AL (hereafter "AFHRA") file no. 248.11-9.

means it required were integrally related and synergistic.[4] Aircraft crossing enemy front lines had to fly at high altitudes to avoid anti-aircraft defenses. The higher the altitude, the harder it was to accurately navigate and bomb "strategic" targets in the enemy interior. Flying during the day considerably eased this burden.[5] To survive in the daylight, bombing aircraft needed sufficient speed to penetrate defenses and outrun enemy pursuit aircraft. Because bomber aircraft, given the limits of aviation technology, outclassed fighters in terms of speed, range, and altitude, bomber formations could fly unescorted to their targets. Precisely destroying "vital" targets required the right weapon – high explosives, rather than gas or incendiary bombs – accurately delivered to avoid unintended collateral effects. These tenets of precision bombing – accurate navigation and targeting, stealthy penetration, and the precise and discriminate destruction of targets – remain just as important today. American precision air power has its roots in the interwar doctrine of high-altitude precision daylight bombing.[6]

This method, however, was not the only alternative available to American airmen – precision bombing was not a predetermined outcome for American air power. Incidents like the successful bombing of warships off the Virginia Capes, the dramatic trial and "excommunication" of Billy Mitchell, the rise of the Air Corps Tactical School, as well as the development of the B-17 and the Norden bombsight, gave positive reinforcement and increasing returns that "locked in" the doctrine of precision bombing

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[3] Notes accompanying drafts of FM 100-20: *Command and Employment of Air Power*, 1943, 2. AFHRA file no. 248.211-1.
[4] Thomas H. Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941* (Washington, D.C.: Office of Air Force History, 1985), 57-58.
[5] "Since precision targets require accurate sighting, they are more conveniently attacked by day when it is not necessary to illuminate the target." Notes accompanying draft of FM 100-20: *Command and Employment of Air Power*, 1943. AFHRA file no. 248.211-1.
[6] Mark Clodfelter, "Pinpointing Devastation: American Air Campaign Planning Before Pearl Harbor," *The Journal of Military History* 58 (January 1994), 75-76.

much like the adoption of the less-than-perfect QWERTY keyboard or the VHS videotape.[7] Other possibilities included the Trenchardian concept of night area bombing that targeted enemy morale rather than infrastructure or the more balanced approach of the early Billy Mitchell or Claire Chennault where pursuit and attack aircraft played an equal or greater role than the strategic bomber.[8] Although not all American airmen accepted precision strategic bombing as a definitive solution, many during the interwar period became so convinced in its correctness that they gave inadequate attention to other alternatives for the airplane in wartime.[9]

Air Power and World War I

Traditional scholarship tends to minimize the impact of World War I on American air power doctrine.[10] The early end to the war in November 1918 (only seven months after American air units first entered combat) and the failure of American industry to

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[7] For a discussion of increasing returns and lock-in as a source of inefficiency, see M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (New York: Simon and Schuster, 1992), 35-37. The period from December 1925 to May 1927 in particular was a kind of ideological "tipping point" in the development of American air power. Besides Mitchell's court martial and the Air Corps Act of 1926, this crucial 18 months saw the exhaustion of the last of the Liberty engines and other excess war stocks, the Air Mail Act of 1925 and the Air Commerce Act of 1926 that took the military services out of commercial aviation, and Lindbergh's solo crossing of the Atlantic. Robert F. Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1907-1960* (Maxwell AFB, AL: Air University Press, 1989), vol. 1, 61.

[8] On the Trenchardian concept, see Tami Davis Biddle, *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas About Strategic Bombing* (Princeton: Princeton University Press, 2002), 76-81 and 131. On Chennault's alternative, see Claire Chennault, *Way of a Fighter* (New York: G.P. Putnam's Sons, 1949), 18-31 and Greer, *The Development of Air Doctrine in the Army Air Arm*, 58-66.

[9] Haywood S. Hansell, Jr., *The Strategic Air War Against Germany and Japan: A Memoir* (Washington, D.C.: Office of Air Force History, 1986), 10; Biddle, *Rhetoric and Reality*, 174.

[10] Tami Davis Biddle, "Learning in Real Time: The Development and Implementation of Air Power in the First World War," in Sebastian Cox and Peter Gray, *Air Power History: Turning Points from Kitty Hawk to Kosovo* (Portland, OR: Frank Cass, 2002), 3-4. For the latest scholarship on the American military experience in the air through the end of World War I, see Herbert A. Johnson, *Wingless Eagle: U.S. Army Aviation Through World War I* (Chapel Hill: University of North Carolina Press, 2001). I.B. Holley argues that airmen tended to ignore the experience of WWI since much of the doctrine that emerged from the war focused on close support of the Army rather than an independent strategic role for the air arm. I.B. Holley, *Ideas and Weapons* (Washington, D.C.: Air Force History and Museums Program, 1997), 159. For

meet demands for airplane production prevented the full flowering of American air power.[11] The combat record of the Air Service included only 150 bombing raids (1174 individual bombing flights) that dropped some 275,000 pounds of bombs.[12] Although limited, the American experience demonstrated how difficult accurate bombing was absent the corresponding technology.[13] Furthermore, wartime interaction with allies and the Air Service's attempts to draw "lessons learned" from the war shaped the initial outlines of American air power theory and doctrine into the 1920's and 1930's.

Lacking their own extensive experience in air power upon entering the war, American airmen borrowed from the experience of others. As General Billy Mitchell later declared, "We were nurtured during the...war under the protecting skirts of the French Republic and the British Empire and ...in everything we did they were our chaperons and mentors."[14] Although the American Air Service never launched its own strategic bombing campaign per se, thirty-six American officers served with the British Independent Air Force, conducting both day and night bombing missions against German

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an early interpretation of the war's influence, see "The Influence of Airplanes on Operations in War." Anonymous lecture at the Field Officer's School, 1919, 7. AFHRA file no. 248.211-121.

[11] Holley, *Ideas and Weapons*, 138-146.

[12] At the time of the Armistice in November 1918, there were 6,861 officers and 51,299 "men" serving in the American Air Service organized into forty-five squadrons with 757 pilots, 481 observers, 740 airplanes, and 77 observation balloons. During the war the Air Service shot down a total of 781 enemy airplanes. Clayton Bissell, *Brief History of the Air Corps and Its Late Developments* (Langley Field, VA: Air Corps Tactical School, 1927), 78-79. Air Force History Support Office, OCLC #10737144. See also Greer, *The Development of Air Doctrine in the Army Air Arm,* 4.

[13] See for example Edgar S. Gorrell, "General Remarks on Bomb Dropping." 27 September 1917. AFHRA file no. 248.22-10D. Gorrell discusses some of the bomb dropping technologies used in the war by the French and the British and the techniques required for accurate bombing.

[14] William Mitchell, "Our Stamped Out Aviation," quoted in Raymond R. Flugel, *United States Air Power Doctrine: A Study of The Influence of William Mitchell and Giulio Douhet at the Air Corps Tactical School, 1921-1935*, unpublished PhD dissertation, University of Oklahoma, 1965, 30-31. See also Greer, *The Development of Air Doctrine in the Army Air Arm,* 7. On the transfer of ideas about bombing from the British and the French to the American Air Service, see Edgar S. Gorrell memo to the Chief of the Signal Corps, "General Remarks on Bomb Dropping," 27 September 1917. AFHRA file no. 248.22-10D.

industrial centers.[15] Dramatic, highly visible events also shaped early American conceptions of air power – Britain was still reeling from a German bombing attack when the Bolling Commission arrived in London two weeks later to survey air requirements for the American army.[16]

Most of the first American plan for strategic bombing, submitted by Lieutenant Colonel Edgar Staley Gorrell in November 1917 and approved by General John J. Pershing in January 1918, was lifted word for word from a document prepared by an English officer, Major Lord Tiverton, in September 1917. Gorrell later acknowledged Tiverton as a source of "much valuable advice." [17] Gorrell's plan followed the Triverton model that called for concentration upon a single industrial target each day rather than General Hugh Trenchard's competing concept for dispersed attacks.[18] Using the original analogy of a drill whose shaft has been broken, Gorrell proposed around-the-clock bombing to destroy "a few certain indispensable targets without which Germany cannot

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[15] Bissell, *Brief History of the Air Corps and Its Late Developments*, 51. A single squadron of dedicated American night bombers saw active service for only two days before the November armistice and was immobilized less than a month later. Holley, *Ideas and Weapons*, 157-158.
[16] George K. Williams, "The Shank of the Drill: Americans and Strategical Aviation in the Great War," *Journal of Strategic Studies* 19/3 (September 1996), 389. See also Michael Howard, "The Concept of Air Power: An Historical Appraisal," *Air Power History* 42 (Winter 1995), 8. The charge of the Bolling Commission, sent to Europe in the summer of 1917, was to make a "broad general survey of the whole aeronautical situation" and to collect technical information concerning available aircraft in the inventories of allies. Bissell, *Brief History of the Air Corps and Its Late Developments*, 43. The Bolling Commission's report had "a marked effect on the whole subsequent doctrinal position of the wartime Air Service." See J.L. Boone Atkinson, "Italian Influence on the Origins of the American Concept of Strategic Bombardment," *Air Power Historian* 4 (July 1957). See also Clodfelter, "Pinpointing Devastation," 77.
[17] The Gorrell plan is in Maurer Maurer, ed., *The U.S. Air Service in World War I*, 4 vols. (Washington, D.C.: GPO, 1978-79), 2, 141-157. Maurer's four-volume work is the official collection of Air Service documents. For a discussion of the genesis and significance of Gorrell's plan, see Clodfelter, "Pinpointing Devastation," 76-84. On the plan's lack of originality and Gorrell's inclination to collect rather than create, see Williams, "The Shank of the Drill" and Biddle, *Rhetoric and Reality*, 38 and 54-55. The Gorrell quote is from his 1919 *Air Service History*, referenced in Atkinson, "Italian Influence on the Origins of the American Concept of Strategic Bombardment," 148.
[18] See Edgar S. Gorrell "Area vs. Precision Bombing" in Maurer, 2, 253. See also Maurer, 4, 150; Biddle, *Rhetoric and Reality*, 36-40; and Williams, "The Shank of the Drill," 390-396.

carry on the war."[19] Gorrell recognized the challenge of accuracy such concentrated attacks posed: "Accurate bombing is a new science and requires the entire time and study of the man who is to shoulder the responsibility for the success or failure during the coming year."[20]

In WWI, the technological promise of the airplane outran its actual capabilities.[21] The primary American air weapon, the DeHaviland DH-4, although relatively effective as an observation aircraft, proved unsuitable as a bomber.[22] The general lack of sophisticated bombsights, navigation equipment, and unaccommodating weather limited the effectiveness of aerial bombardment.[23] As one airman described it, the American Air Service "...was neither equipped nor trained to bomb with accuracy. The 1st Day Bombardment Group was misnamed. It was a group, it was the first group, and it was a daytime group, but without bombsights or means of accurate bombing, it was never a bombardment group. It was, perhaps, a poorly-equipped attack unit attempting high altitude operations."[24] A contemporary analysis of Allied bombing between 1 March and 20 June 1918 illustrated the early technological limitations of air power: only three out of 141 attempts to bomb railway stations behind enemy lines were known to have succeeded.[25]

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19 Maurer, 4, 143. Quoted in Clodfelter, "Pinpointing Devastation," 80.
20 Maurer, 4, 154.
21 On the evolution of air weapons in the First World War, see Holley, *Ideas and Weapons*, especially 118-146. See also Biddle, "Learning in Real Time," 3-20.
22 Bissell, *Brief History of the Air Corps and Its Late Developments*, 66.
23 Bissell, *Brief History of the Air Corps and Its Late Developments*, 72-73.
24 L.S. Kuter, "American Air Power – School Theories vs. World War Facts," Maxwell Field, AL: May 1936. AFHRA file no. 248.11-2. The American 1st Day Bombardment Group, despite its name, flew interdiction and attack missions, not strategic bombing missions. Bissell, *Brief History of the Air Corps and Its Late Developments*, 51.
25 Biddle, "Learning in Real Time," 7.

Although the American Air Service lacked both the quality and quantity of aircraft to carry out the plan, Gorrell's preliminary script influenced later American air planners.[26] First Lieutenant Laurence S. Kuter, an instructor at the Air Corps Tactical School (ACTS) from 1935 to 1937 and one of four key individuals that wrote the initial American air plan for World War II, devoted an entire lecture to the Gorrell plan at ACTS, calling it "the earliest, clearest, and least known statement of the American conception of the employment of air power."[27] Gorrell's plan was an influential first cut that foreshadowed many of the elements of ACTS' "industrial web" theory and the American doctrine for high-altitude precision daylight bombing.

After the war, Gorrell oversaw the writing of a history of the Air Service and a "Final Report" for General Pershing.[28] In compiling "lessons learned" from the experience in the air, Gorrell interviewed leading American aviators and conducted an investigative survey of Allied bombing efforts.[29] Although the survey teams often found it difficult to distinguish the effects of aerial bombardment from that of long range artillery,[30] they were sufficiently impressed with strategic bombardment's potential for indirect effects to include production losses and the costs of defenses.[31] One particular incident, a raid on Thionville in July 1918 where a bomb hit a munitions train causing

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[26] Donald Wilson, an instructor at the Air Corps Tactical School in the 1930's, borrowed Gorrell's drill and shaft analogy in promoting his "industrial web" theory: "The military force is a spearhead, capable of being thrust forward only so long as the good strong shaft of national morale and resources remains intact. [It is] obvious that the breaking of the shaft will prevent effective use of the spearhead." Donald Wilson, "Origin of a Theory of Air Strategy," *Aerospace Historian* 18 (Spring 1971), 21.
[27] L.S. Kuter, "Air Power – The American Concept," Washington, D.C., HQ USAF, n.d. AFHRA file no. 167.6-50. See also Greer, *The Development of Air Doctrine in the Army Air Arm*, 10 and Clodfelter, "Pinpointing Devastation," 83.
[28] Maurer, 4, 1-3. See also James J. Cooke, *The U.S. Air Service in the Great War* (Westport, CT: Praeger, 1996), 219-222.
[29] The reports are available in Maurer, 4, 368-562. The statistical and narrative summaries from 4, 492-505 are particularly enlightening. See also Maurer's introduction to the survey, 4, 363-367. The results of the survey are summarized in Biddle, *Rhetoric and Reality*, 62-67.
[30] Holley, *Ideas and Weapons*, 161-162.

secondary explosions and fires in surrounding structures, highlighted the potentially disproportionate effects of bombing.[32] The conclusion of the American bombing survey criticized British bombing as inefficient, lacking a "predetermined program carefully calculated to destroy by successive raids those industries most vital in maintaining Germany's fighting forces." Americans were particularly critical of British attacks against cities in general, rather than against more "legitimate" targets within these cities.[33] A more systematic and scientific analysis of target sets, combined with bombs more precisely aimed at key targets, would have been more efficient and more effective.[34]

There were other influences on early American conceptions of air power beyond that of their allies and ideological cousins, the British. The most notable of these came from Italian theorists and aircraft designers.[35] Italian airmen were arguably the founding fathers of aerial bombing, having been the first to drop bombs from airplanes during their war in Libya in 1911.[36] Italy was also the only ally engaged in a systematic strategic bombardment campaign when the Americans entered the war.[37] During the Bolling

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[31] Biddle, *Rhetoric and Reality*, 63-64.
[32] Maurer, 4, 400-401
[33] Maurer, 4, 501-502.
[34] Biddle, *Rhetoric and Reality*, 66-67. Maurer, 4, 504. See also Williamson Murray, "Strategic Bombing: The British, American, and German Experiences," in Williamson Murray and Allan R. Millett, eds., *Military Innovation in the Interwar Period* (New York: Cambridge University Press, 1996), 99.
[35] See Atkinson, "Italian Influence on the Origins of the American Concept of Strategic Bombardment." See also Phillip S. Meilinger, "Giulio Douhet and the Origins of Airpower Theory," in Phillip S. Meilinger, ed., *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell AFB, AL: Air University Press, 1997), especially 6-9; and Bernard Brodie, *Strategy in the Missile Age* (Princeton, NJ: Princeton University Press, 1965), 71-106.
[36] The Turks, incidentally, claimed that the first bomb dropped from an Italian airplane hit a hospital. Stephen Budiansky, *Air Power: The Men, Machines, and Ideas That Revolutionized War, From Kitty Hawk to Gulf War II* (New York: Viking Penguin, 2004), 45.
[37] Meilinger, "Giulio Douhet and the Origins of Airpower Theory," 3. Also in Richard J. Overy, "Introduction," in Sebastian Cox and Peter Gray, *Air Power History: Turning Points from Kitty Hawk to Kosovo* (Portland, OR: Frank Cass, 2002), ix. On the Italians as the first to wage a strategic bombardment campaign, see Atkinson, "Italian Influence on the Origins of the American Concept of Strategic Bombardment," 144.

Commission's visit to Italy in 1917, American observers (including Gorrell) were greatly impressed with Italy's bombing campaign against Austria and with Gianni Caproni, the influential aviation engineer and aircraft designer who built the Italian bomber force.[38] After his exile to Europe in 1921-1922, General Billy Mitchell remarked that he had met "more men of exceptional ability in Italy than we did in any other country."[39] Not only British, but also Italian theorists, played an important role in the formulation of an American way of air warfare.[40]

One Italian in particular had a profound influence on early American air power thinking. In his book, *The Command of the Air*, Giulio Douhet argued that intensive bombing could render a quick decision in war, avoiding the horrors of prolonged trench warfare.[41] "War is won by crushing the resistance of the enemy; and this can be done more easily, faster, more economically, and with less bloodshed by directly attacking that resistance at its weakest point."[42] Douhet's weakest points were the "vital centers" of a modern nation – industry, transportation, infrastructure, communication nodes, government buildings, and the will of the people – that could be affected from the air using a synergistic combination of gas, incendiaries, and high explosives. Although he wrote little about bombing accuracy, Douhet described the airplane itself as a precision instrument of war, analogous to a modern precision-guided munition – "...we can

[38] Clodfelter, "Pinpointing Devastation," 77-78. See also Atkinson, "Italian Influence on the Origins of theAmerican Concept of Strategic Bombardment," 142-144.
[39] Alfred F. Hurley, *Billy Mitchell: Crusader for Air Power* (Bloomington: Indiana University Press, 1975), 75. Also in Futrell, *Ideas, Concepts, Doctrine*, 1, 38.
[40] Boone Atkinson suggests that later American air power theorists downplayed the Italian connection to distance themselves from Italy's military misfortunes in WWI. Atkinson, "Italian Influence on the Origins of the American Concept of Strategic Bombardment," 148. Douhet's connections with Mussolini and Italian fascism probably also contributed to later American denial.
[41] Giulio Douhet, *The Command of the Air*, Dino Ferrari, trans., reprint of the 1942 edition (Washington, D.C.: Air Force History and Museums Program, 1998).
[42] Douhet, *The Command of the Air*, 196.

compare the airplane to a special gun capable of firing shells a distance equal to its flying range, and with a special observer to guide the shells to their targets."[43]

Few American airmen actually read Douhet's writings, but his ideas were nevertheless widely known in the interwar American air forces.[44] Both Gorrell and Mitchell were disciples of Douhet's gospel, although both men uniquely interpreted Douhet's theories.[45] Partial translations of Douhet's writings reached the Air Service after Mitchell's conversations with Douhet in 1922, and by the mid-1930's several articles discussing Douhet appeared in American military publications.[46] By 1934, Douhet's ideas on air warfare were being taught at the Army War College.[47] Originally

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[43] Douhet, *The Command of the Air*, 200.

[44] Eugene M. Emme, "Technological Change and Western Military Thought, 1914-1945," *Military Affairs* 24/1 (Spring 1960), 10-11. See, for example, C. deF. Chandler, "Air Warfare Doctrine of General Douhet," U.S. Air Services (May 1933). AFHRA file no. 248.211-32.

[45] I.B. Holley, "Reflections on the Search for Airpower Theory," in Phillip S. Meilinger, ed., *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell AFB, AL: Air University Press, 1997), 580. Gorrell became with Douhet's theories indirectly through Caproni, Mitchell during his trip to Europe in 1922. Meilinger, "Giulio Douhet and the Origins of Airpower Theory," 6-7 and 33. See also Atkinson, "Italian Influence on the Origins of the American Concept of Strategic Bombardment," 145-147; Brodie, *Strategy in the Missile Age*, 71-72, note 1; and Meilinger, "Giulio Douhet and the Origins of Airpower Theory," 6-7.

[46] Hurley, 75-76 and 146-147; Russell F. Weigley, *The American Way of War: A History of United States Military Strategy and Policy* (New York: Macmillan Publishing Co., Inc., 1973), 226-227; and Clodfelter, "Moulding Airpower Convictions," 98-99. A five-page extract of *Command of the Air* was prepared by the War Department Military Intelligence Division in March 1922 that made its way into the files of the Air Service Plans Division. A translation of the first 100 pages of the book arrived at the Air Service Field Officers School in May 1923. Futrell, *Ideas, Concepts, Doctrine*, 1, 39. A summary of *Command of the Air* was also sent by the Italian air attache in Washington to Lester Gardner, editor of Aviation magazine in 1922, who had discussed the work with Mitchell. Hurley, 75. See also Meilinger, "Giulio Douhet and the Origins of Airpower Theory," 33. Copies of Douhet's "The War of 19—" were in the Air Corps Tactical School library as early as November 1931. See "Translation of Article From 'Rivista Aeronautica,'" March 1930. AFHRA file no. 248.501-46G. See also Futrell, *Ideas, Concepts, Doctrine*, 1, 69. Writing during the Second World War, Edward Warner claimed that Douhet's writings did not reach the Air Corps until 1932. See Edward Warner, "Douhet, Mitchell, Seversky: Theories of Air Warfare," In Edward Mead Earle, ed., *Makers of Modern Strategy: Military Thought from Machiavelli to Hitler* (Princeton: Princeton University Press, 1971), 489. Bernard Brodie wrote that a 1932 French translation of a substantial part of the second edition of Douhet's *The Command of the Air* was first available to Air Corps officers in 1933. Brodie, *Strategy in the Missile Age*, 73.

[47] See Maj. George H. Weems, "General Douhet's 'Air Warfare,'" Washington, D.C.: Army War College, May 1934. AFHRA file no. 248.211-65M. Weems' "Memo for the Assistant Commandant" answered the question "What principles, if any, enunciated by General Giulio Douhet in his work entitled 'Air Warfare' are applicable to the strategic or tactical employment of the U.S. Air Corps?" The memo also includes summary answers to a questionnaire given to Air Corps officers attending Air War College on the basic tenets of Air Corps doctrine.

articulated with Italian circumstances in mind, Douhet's thoughts on the nonlinear potential of the airplane, the priority of air supremacy or "command of the air," the need for a relentless aerial offensive, and the invulnerability of the bomber, became basic tenets of interwar American air power doctrine.[48]

Not only Douhet's ideas, but also his methodology, influenced early American air power doctrine. Although American air theorists preferred materiel targets to Douhet's population centers, they nevertheless saw utility in his "scientific" methods for calculating the effects of bombing. Douhet reduced air power into "units of bombardment" of ten planes each loaded with two tons of bombs that would create "units of destruction" the area of a circle 500 feet in diameter. These "units of destruction" were to be laid in a "uniformly spaced checkerboard" for the desired destructive effects, 500 tons of bombs being sufficient to destroy a large city and its inhabitants.[49] American air planning at the Air Corps Tactical School and in the days immediately prior to American entry into World War II followed Douhet's mechanistic example for determining air power requirements.[50] His largely unchallenged and unsupported

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[48] Bernard Brodie argued that "Douhet's influence on the United States Air Force has actually been much greater than that of its own great leader, Brigadier General William A. Mitchell." Brodie, *Strategy in the Missile Age*, 77. Laurence Kuter rejected this claim: "The American idea is frequently and falsely attributed to a foreigner. The foreigner ...was, of course, Giulio Douhet." L.S. Kuter, "Air Power – The American Concept," Washington, D.C., HQ USAF, n.d. (incorrectly dated 1938). AFHRA file no. 167.6-50

[49] Douhet, *The Command of the Air*, 35-41. See also Brodie, *Strategy in the Missile Age*, 88-90; Brodie, "The Heritage of Douhet," *Air University Quarterly Review* 6/2 (Summer 1953), 69ff; and Warner, "Douhet, Mitchell, Seversky," 491-492.

[50] See Stephen M. Rinaldi, "Complexity Theory and Airpower: A New Paradigm for Airpower in the 21st Century," in David S. Alberts and Thomas J. Czerwinski, eds., *Complexity, Global Politics, and National Security* (Washington, D.C.: NDU Press, 1997), 262-280 and Barry Watts, *The Foundations of U.S. Air Doctrine: The Problem of Friction in War* (Maxwell AFB, AL: Air University Press, 1984), 6-7 and 18-22.

reductionism encouraged a false but alluring "scientism" that appealed to American air power theorists seeking technological solutions to complex social problems.[51]

Autonomy for the American Air Arm

Although the experience of World War I demonstrated the value of pursuit and attack aircraft in support of the land forces,[52] the struggle for independence from the Army drove airmen away from supporting roles toward "strategic" air power. Through strategic attack, the air arm could independently achieve potentially decisive results for a comparatively small investment of military resources. Land and naval forces, unlike air forces, could not strike a country's vital centers without first fighting their way through an opponent's defensive barriers.[53] In the opinion of airmen, strategic bombing was more efficient than either land or naval power. The nonlinear potential of air power justified the sovereignty of the air forces.

American airmen, as agents of the larger Army system, played a leading role in the interwar struggle against what General Douglas MacArthur once called "the tendency of the Navy to come ashore." At the same time, airmen fought to keep the Army from

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[51] Meilinger, "Giulio Douhet and the Origins of Airpower Theory," 21-23. For another critique that discusses the allure of Douhet's simplicity and tests Douhet's theories against operational realities, see Michael J. Eula, "Giulio Douhet and Strategic Air Force Operations: A Study in the Limitations of Theoretical Warfare," *Air University Review* 37/6 (Sep-Oct 1986), 94-99.

[52] See, for example, an article prepared by a Col. Hartney for *National Service Magazine* immediately after WWI. Col. Hartney, portraying the chivalric nature of air combat and the airman as the new "champ d'honneur," discusses the shift of aerial missions from observation to "destroying the enemy on the ground," not deep behind the lines, but along the trenches where friendly forces are in contact. Col. Hartney, "Air Tactics," n.d., AFHRA file no. 248.211-65P. Somewhat ironically given his later history, Billy Mitchell, writing during and immediately after the war, also acknowledged the predominance of support aviation over strategic bombardment. Pursuit, not bombardment, was the "basis of an air force." Although the first objective of the air force was to "whip the hostile air force," this was done for the sake of freeing up air power to attack enemy formations on the ground, especially troops in reserve. See "Statement of Brigadier General William Mitchell, Assistant Chief of the Air Service," 4 January 1921. AFHRA file no. 248.211-16E.

exercising excessive control over the air mission and the organization of the air forces. Between 1919 and 1937 there were some nineteen different groups that met to define the roles of American air power and to more clearly draw lines of demarcation between the competing military services.[54] The intricately interrelated rivalries between the Army, Navy, and the Army Air Corps during the interwar period gave further impetus to the emerging doctrine of high-altitude precision daylight bombing.

The airplane, by extending the reach of each service, helped to blur the traditional dividing lines between Army and Navy missions. Encouraged by the War Department, American airmen after World War I took up coastal defense as a distinctive mission and a logical way to justify air power.[55] As Thomas Milling told the Morrow Board, "[I]t needs no great stretch of the imagination to foresee the time when sea supremacy will rest entirely in air power."[56] Airmen contended that airplanes were not only more effective, but also more efficient, than vulnerable capital ships at stopping both naval invasion and aerial attack from offshore.[57] Charles Menoher, head of the Air Service from 1919-1921,

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[53] "A navy cannot work on land; an army cannot work on water; an air service can work over both." Mitchell, *Our Air Force*, 221.

[54] Flugel, *United States Air Power Doctrine*, 157-158. See also Edwin L. Williams, Jr., "The Legislative History of the Air Arm," *Military Affairs* 20/2 (Summer 1956), 81-93; and Peter Faber, "Interwar US Army Aviation and the Air Corps Tactical School: Incubators of American Airpower," in Phillip S. Meilinger, ed., *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell AFB, AL: Air University Press, 1997), 208-210. As Mason Patrick remarked in 1928, "The Air Service, or rather the air effort of the United States since we entered the World War, has probably been the most investigated activity ever carried on by the United States Government." Quoted in H.H. Arnold, *Global Mission* (New York: Harper & Brothers, 1949), 164.

[55] James P. Tate, *The Army and Its Air Corps: Army Policy Towards Aviation, 1919-1941* (Maxwell AFB, AL: Air University Press, 1998), 59-82. See also Wesley Frank Craven and James Lea Cate, eds. *The Army Air Forces in WWII*, Vol. 1, *Plans and Early Operations, January 1939 to August 1942* (Washington D.C.: Office of Air Force History, 1983), 61-63; and Faber, "Interwar US Army Aviation and the Air Corps Tactical School," 192-193.

[56] "Testimony of General M.M. Patrick [and others] before the Morrow Board," 21 September 1925, 79. AFHRA file no. 248.211-6V. Quoted in Faber, "Interwar US Army Aviation and the Air Corps Tactical School," 195.

[57] On the debate between the Navy and the Army air arm regarding coastal defense, see Greer, *The Development of Air Doctrine in the Army Air Arm*, 33-36. Mitchell contended that given an annual budget of $50,000,000, just half the cost of one battleship, the Air Service could within two years decisively

argued that for the price of one battleship the Air Service could provide one thousand bombers to overwhelm a seaborne attack.[58] Furthermore, the limitations on naval power imposed by the disarmament treaties and the need to divide the fleet between two oceans with the vulnerable Panama Canal in between further fated the future power of the American navy.[59] Powerful air forces, not naval forces, were a more appropriate answer to the foreseeable strategic challenges facing the United States.

Destroying old battleships became a proving ground not just for air power, but also for air power *precision* in the 1920's. Brigadier General Billy Mitchell was particularly enthusiastic about air power's potential against naval vessels; for Mitchell, sinking old battleships became a personal crusade.[60] Successfully hitting naval vessels demanded accuracy and precision, not area bombing and as Mitchell asserted, aerial bombs were not only more deadly than cannon shell fired from ships or coast artillery—they were also more accurate.[61] Successful tests from 1920-1923, in which the Air Service aircraft sank captured German warships and decommissioned ships from the American fleet, seemed to confirm Mitchell's conclusion.[62] The tests, although

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control the air in any theater of operations. McClendon, 52. See also William Mitchell, *Our Air Force* (New York: E.P. Dutton & Co., 1921), 67.

[58] Faber, "Interwar US Army Aviation and the Air Corps Tactical School," 196.

[59] Faber, "Interwar US Army Aviation and the Air Corps Tactical School," 197. On Mitchell's role in the Washington Naval Conference of 1921-1922 and the impact of the test bombing of battleships on the decisions of the conference, see Hurley, *Billy Mitchell*, 70-71.

[60] "It is the belief of the majority of Air Officers in all Services that the development of the Air Service will mean the extinction of navies on the surface of the ocean in the future." William Mitchell, "Tactical Application of Military Aeronautics," 1923(?), 12. AFHRA file no. 248.211-65K. See also William Mitchell, "Has the Airplane Made the Battleship Obsolete?" *World's Work* (April 1921), 550-555. On Mitchell's crusade against the Navy, see especially Samuel F. Wells, Jr., "William Mitchell and the *Ostfriesland*: A Study in Military Reform," *The Historian* 26/4(August 1964), 538-562. See also Hurley, *Billy Mitchell*, 56-72; Cooke, *Billy Mitchell*, 123-139; and Greer, *The Development of Air Doctrine in the Army Air Arm*, 33-34.

[61] See, for example, "Statement of Brigadier General Mitchell, Assistant Chief of the Air Service." 4 January 1921, 7. AFHRA file no. 248.211-16E.

[62] Greer, *The Development of Air Doctrine in the Army Air Arm*, 35. See also Hurley, *Billy Mitchell*, 67-69.

admittedly unfair,[63] nevertheless put stringent operational demands on the young Air Service, most notably in the refinement of existing capabilities for the accurate delivery of bombs against surface targets.[64]

Having lost the argument over the power of the bomber against the battleship, the Navy initiated a five-year expansion of shore-based aircraft in 1927 that appeared to Mason Patrick, the Chief of the Air Corps, to be a move to take over all bombardment aviation.[65] The January 1933 MacArthur-Pratt Agreement delineated the roles of the Army and Navy in coastal defense and the directive "Employment of Army Aviation in Coast Defense" solidified the mission for the Air Corps. The competition between the services continued unabated, nonetheless, throughout the 1930's.[66] The Navy rescinded the MacArthur-Pratt agreement in 1935 as both services continued to cross the newly drawn lines, the Navy building more naval air stations on shore and the Army Air Corps extending the operating range of reconnaissance and bomber aircraft beyond the

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[63] In the tests against the *Ostfriesland*, the most famous of the trials, the German battleship was anchored and undefended. Furthermore, Mitchell and the Air Service dropped their bombs from an unrealistically low altitude to ensure their accuracy. Although the Navy offered the Air Service an unmanned and radio-controlled battleship, Mitchell declined the offer. Mitchell knew how hard a moving target would be to first find, and then hit. "He preferred a sitting duck." Holley, "Reflections on the Search for Airpower Theory," 582.

[64] Prior to the 1921 bomb tests, aircrews were drawn from all across the United States to form a new unit, the First Provisional Brigade, eventually under the direct charge of Mitchell. The Brigade practiced against mock ships near Langley Field in Virginia. Since the Air Service lacked bombing experience, Mitchell sought technical guidance from the Italian and French air attaches Guidoni and de Lavergne, as well as from Alexander de Seversky, a Russian naval aviator who had flown bombing missions against German shipping in the Baltic in the First World War. Hurley, *Billy Mitchell*, 66. For a personal account from one of the participants in the tests, see William C. Sherman, *Air Warfare*, reprint of the 1926 edition (Maxwell AFB, AL: Air University Press, 2002), 253-258. See also Bissell, *Brief History of the Air Corps and Its Late Developments*, 51.

[65] Tate, *The Army and Its Air Corps*, 61-62.

[66] Futrell, *Ideas, Concepts, Doctrine*, 66 and 76. See also Faber, "Interwar US Army Aviation and the Air Corps Tactical School," 198-199; and Jeffery S. Underwood, *The Wings of Democracy: The Influence of Air Power on the Roosevelt Administration, 1933-1941* (College Station, TX: Texas A&M University Press, 1991), 35.

distances mandated by the agreement.[67] The ongoing competition with the Navy over roles and missions encouraged the development of technology and tactics for precision bombing, increased Air Corps dogmatism over emerging doctrine, and further inspired airmen in their pursuit of autonomy from the U.S. Army.[68]

The struggle for autonomy from the Army in the interwar period did not evolve in a steady, linear progression as a simple chronology might suggest. Like the coevolutionary competition with the Navy, it occurred in a series of fits and starts, ebbing and flowing with the pull of political and budgetary forces from within and outside the system.[69] The qualitative impacts of this episode on the development of precision air power are somewhat murkier than the published "facts" found in organizational charts, Congressional testimonies, and government procurement budgets. Besides defining organizations and deciding the allocation of resources, the air arm's peacetime separatist movement fueled "growing personal bitterness" in both airmen and soldiers that gave positive feedback to the cycle of competition, resentment, and divergence.[70]

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[67] The MacArthur-Pratt agreement limited the range of reconnaissance and bomber aircraft to the distance that a fast Navy unit could cruise in 24 hours. "The Strategic Bomber," *Air University Review* 8/1 (Summer 1955), 98. In 1938, after three B-17's managed to successfully intercept the Italian ocean liner *Rex* 700 miles east of New York, the Navy persuaded the Secretary of War to limit Army bombers to a distance of no more than 100 miles from the coast. Greer, *The Development of Air Doctrine in the Army Air Arm*, 90-91 and 97.

[68] Greer, *The Development of Air Doctrine in the Army Air Arm*, 67.

[69] See R. Earl McClendon, *The Autonomy of the Air Arm* (Washington, D.C.: Air Force History and Museums Program, 1996) (reprint of 1948 edition). The Air Service remained a part of the Army Signal Corps until May 1918 when aviation matters were divided between the Division of Military Aeronautics and the Bureau of Aircraft Production. The Army Reorganization Act of 1920 permanently consolidated these agencies into the Air Service, recognizing it as a coequal combatant arm of the Army. The Air Corps Act of 1926 renamed and reorganized the Air Service in the model of the Navy's Marine Corps. Although organizationally autonomous on paper, administrative functions like promotion, assignment, procurement, and budgets remained with the Department of the Army and the Office of the Secretary of War. In 1935, in a compromise measure between the Air Corps and the Army, tactical combat units of the Air Corps were consolidated under the GHQ Air Force to facilitate independent strategic action. The Army Air Forces were created in June 1941 by Army Regulation 95-5, fully consolidating tactical control and administrative functions under the direction of airmen. Greer, *The Development of Air Doctrine in the Army Air Arm*, 149.

[70] Greer, "Air Arm Doctrinal Roots, 1917-1918," 203. Weigley, *The American Way of War*, 240.

The austere fiscal environment shaped the nature of this competition and of American air power in the interwar years. The scarcity of available means necessarily limited the manifestations of doctrinal visions. The military, thanks to the predominance of antimilitarism after the First World War and the spendthrift policies of the Coolidge and Hoover administrations, saw little of the economic prosperity of the 1920's.[71] Although the Air Corps Act of 1926 authorized an expansion of the Air Corps to 20,000 men and 1800 aircraft, Congress failed to fund the expansion. As one senior officer later recalled, "Very few aircraft were purchased, personnel salaries were reduced or held down by various means, reserve officers were refused regular commissions, and flying cadets and enlisted pilots were used instead of officers, just to reduce the payroll."[72]

After 1929, the Great Depression slowed Air Corps growth even further. Ranging from $25-30 million in the years after WWI, Air Corps appropriations fell to barely half that amount by the mid-1920s, gained slightly at the end of the decade but then fell again to post-war levels in 1934.[73] The need for economy in military budgets supported the potential nonlinear economies of precision bombardment.[74] A large bomber fleet was unrealistic. A small fleet that could hold its own by precisely destroying a few select targets on the other hand held great appeal.[75]

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[71] "The Strategic Bomber," 91.
[72] General Earle E. Partridge, USAF Ret., Oral History #610, August 1966, 7. AFHRA file no. K239.0512-610.
[73] Figures for Air Corps appropriations vary widely for the period. The most reliable and comprehensive are in Maurer Maurer, *Aviation in the U.S. Army, 1919-1939* (Washington, D.C.: Office of Air Force History, 1987), 475-477. Maurer's figures include not only direct and indirect appropriations, but also money taken from War Reserves. For more pessimistic estimates of Air Corps budgets, see Underwood, *Wings of Democracy*, 30 and Clodfelter, "Molding Airpower Convictions," 105.
[74] Tate, *The Army and Its Air Corps*, 12-15.
[75] Williamson Murray, "The U.S. Air Force: The Past as Prologue," in Michael Mandelbaum, ed., *America's Defense* (New York: Holmes and Meier, 1989), 238.

The availability of means was the direct result of the Air Corps' success or failure in their struggle with the larger Army. The Army and Air Corps were engaged in a zero sum game – resources dedicated to the Air Corps subtracted from resources available to other branches of the Army.[76] Contrary to airmen's perceptions, Air Corps' budgets taken as a percentage of Army appropriations generally increased throughout the period.[77] From 1926 to 1940, the combined research and development money for all the rest of the combat arms branches of the Army amounted to only 60% of that allocated to the Air Corps alone.[78] Up until the true expansion years of 1938 and 1939, this zero sum competition for budget shares only heightened differences between airmen and their Army brethren.

The case of bomber acquisition in the late 1930's vividly illustrates the closely-knit relationship between available means and doctrinal ends. A doctrine for long-range strategic bombing required a suitable long-range bomber. Although the Air Corps requested the purchase of sixty-five Boeing B-17 Flying Fortresses after a fly off at Wright-Patterson Field in 1934, the Army instead chose to purchase 133 Douglass B-18's, a less expensive two-engine bomber well-suited to close air support and air interdiction, but wholly inadequate for the mission of high-altitude precision daylight bombing.[79] Only the increasingly threatening international environment and the political support of the President, however, saved the Air Corps and its emerging doctrine for

[76] For example, under the Coolidge Economy Program, funds for the recommended 5-year expansion of the Air Corps authorized by the 1926 Air Corps Act could only come from some other reduction in the War Department budget. Tate, *The Army and Its Air Corps*, 59.
[77] See Maurer, *Aviation in the U.S. Army*, 475-476.
[78] David Mets, "Introduction," in Byrd, *George C. Kenney*, xx-xxi.
[79] The Air Corps wanted the 65 B-17's instead of the 185 other planes previously authorized for 1936. The unfortunate crash of the B-17 prototype only further convinced the War Department of the unsuitability of the B-17. Although the War Department refused to put the B-17 into production, it did authorize the

strategic bombing.[80] Competition for resources between the Air Corps, the Army, and the Navy and the economic and political context of these battles had a direct impact on the emerging character of American air forces and the nature of air doctrine in the interwar period.

The Role of Agency

The emergence of an independent doctrine for precision air power was more than just the result of the impersonal competition between military organizations. In a nonlinear world where futures are highly contingent and uncertain, unique individuals, not just generic systems, play an important part in shaping systemic outcomes.[81] Through the process of "directed evolution," influential people provide selection pressures that steer the evolution of complex adaptive systems. Air power history is as much biography as it is the study of organizations and technology.

One biography clearly stands above the rest in the early history of American air power. As one reviewer recently noted: "One issue and one man dominate U.S. Army aviation history between the end of WWI and the mid-1920's. Army air independence was the issue and Billy Mitchell was the man."[82]

Like Douhet, Mitchell was disgusted with the futility of the land battle in World War I and saw the airplane as a revolutionary solution. Although Mitchell's ideas may

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purchase of 13 B-17's that would become the core of the American long-range bomber force in WWII. Tate, 164.

[80] Tate, *The Army and Its Air Corps*, 170-171. See below on Roosevelt's advocacy of air power.

[81] On the role of individuals in the evolution of complex adaptive systems, see Murray Gell-Mann, *The Quark and The Jaguar* (New York: W.H. Freeman and Company, 1994), 297-301. See also Malcolm Gladwell, *The Tipping Point: How Little Things Can Make a Big Difference* (Boston: Little, Brown, and Co., 2000), 30-88.

[82] Kenneth P. Werrell, Review of James Cooke's *Billy Mitchell* and Robert P. White's *Mason Patrick and the Fight for Air Independence. The Journal of Military History* 66/4 (October 2002), 1225.

not have been wholly original, the bravado with which he promoted these ideas was entirely his own. As Mitchell reasoned, "Changes in military systems come about only through the pressure of public opinion or disaster."[83] Preferring public opinion to military disaster, Mitchell became a dramatic salesman for the air power idea whose influence has steered the formulation of American air power doctrine through the present day.[84]

There were in reality two Billy Mitchells: an earlier realist guided by the exigencies of his WWI experience, the limitations of technology, and the American strategic environment; and a later visionary, encouraged by foreign theorists and the promise of technological advance, no longer tied down by the responsibilities of military service.[85] The pre-1926 Mitchell campaigned for an independent air power mission, coastal defense providing the most likely fit, to be achieved by a balanced air force that combined Pursuit, Attack, and Bombardment aviation. Air power, although independent,

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[83] Mitchell, *Winged Defense*, xviii. See also Craven and Cate, 1, 25.

[84] Raymond Flugel contends that it was not Mitchell, but Douhet, who had the greatest influence on the development of American strategic air power doctrine in the 1920's and 1930's. Flugel, *United States Air Power Doctrine*. Although Douhet undoubtedly influenced American thinking (see above), there were key differences between the American theories of HAPDB and the "industrial web," that Flugel inadequately addresses. As Robert Finney asserts: "...Douhet was never really in vogue at the Tactical School. His advocacy of mass area bombing at night was a variance with the ACTS concept of daylight precision bombardment of pinpoint targets." Robert T. Finney, *History of the Air Corps Tactical School, 1920-1940*, reprint of the 1955 edition (Washington, D.C.: Air Force History and Museums Program, 1998), 58.

[85] See especially Weigley, *The American Way of War*, 226-236 and 515, note 2; and Stephen L. McFarland, *America's Pursuit of Precision Bombing, 1910-1945* (Washington, D.C.: Smithsonian Institution Press, 1995), 76-77. Haywood Hansell ascribes Mitchell's dual personality to the two paths he chose to follow: "The first sought to determine the impact of air power upon the established modes of warfare; the second sought to define an entirely new mode of warfare which was reserved to the mission of air power alone. The first path led General Mitchell to contend that naval forces could not perform their traditional role of coast defense within the range of hostile air power, whereas friendly air forces could perform this defensive role. The second path prompted him to contend that air power could be decisively applied directly against the economic, industrial, and social system of a hostile nation, far behind the surface barriers of its defending armies and navies." Haywood S.Hansell, Jr., *The Air Plan That Defeated Hitler* (Atlanta: Higgins-MacArthur/Longino & Porter, Inc.), 1972, 8-9.

was best used in concert with the surface forces.[86] The post-court martial Mitchell, moving further from wartime experience and looking for more spectacular ideas to maintain the limelight he so loved, however, advocated a doctrine that prioritized strategic bombardment over pursuit aviation.

Neither Mitchell advocated a theory of air power that precisely matched the tenets of high-altitude precision daylight bombing.[87] Mitchell's obsession with bombing ships was de facto precision, and his vision included, among other things, the future development of precision-guided munitions.[88] Like other theorists, the early Mitchell was taken with the nonlinear possibilities of aerial bombardment, frequently referring in his books to dramatic cases where a few well-placed bombs caused the utter devastation of vulnerable targets like ammunition plants or trains loaded with gasoline or ammunition.[89] Translating these incidents to the strategic level, Mitchell campaigned for concentrated air attacks against the "vital centers" (a term borrowed from Douhet) of an enemy nation. "The advent of air power which can go straight to the vital centers and

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[86] See, for example, Mitchell's "Provisional Manual of Operations" published in December 1918 in Maurer, 2, 267-301. See also his "Tactical Application of Military Aeronautics," 1923(?). AFHRA file no. 248.211-65K. (This is apparently William Sherman's copy from Field Officer's School at Langley.)
[87] Emphasizing manufacturing centers as the source of the munitions of war, Mitchell concluded that, "The destruction of manufacturing centers and material things brings the conflict to a quicker conclusion." William Mitchell, "Notes on the Multi-motored Bombardment Group, Day and Night," Washington, D.C., n.d. AFHRA file no. 248.222-57. Given the superiority of the pursuit airplane to the bomber and the technological difficulties of hitting targets from a safe altitude even in the daytime, Mitchell preferred night bombardment with slower airplanes that could carry more bombs. "[G]reat accuracy resulted from Night Bombardment, as they could fly low down, very close to their target." William Mitchell, *Our Air Force* (New York: Dutton, 1921), 62-63. See also Laurence S. Kuter, "Air Power – The American Concept," Washington, D.C.: HQ USAF, n.d., 16-19. AFHRA file no. 167.6-50. Kuter's paper uses extracts from Mitchell's "Notes on the Multi-motored Bombardment Group" to argue that it was Mitchell, not Douhet, who was the founder of the American idea of strategic bombardment.
[88] Mark Clodfelter, "Molding Airpower Convictions," 108. In his "Notes on the Multi-motored Bombardment Group, Day and Night," Mitchell described the airplane as "a moveable platform for launching explosive projectiles," whose accuracy "is greater than any other agency yet devised." Mitchell, "Notes on the Multi-motored Bombardment Group."
[89] See for example Mitchell, *Our Air Force*, 64-66. Mitchell himself had been on the receiving end of a German night bombardment raid in 1917 that gave him a "wholesome respect for the material and morale effects of bombardment." Craven and Cate, 1, 11.

either neutralize or destroy them has put a completely new complexion on the old system of making war. It is now realized that the hostile main army in the field is a false objective and the real objectives are the vital centers."[90] More correctly described as the intellectual grandfather, not father, of precision bombardment, Mitchell's call for aerial attacks against vital centers became the core idea of American air power.[91]

Mitchell further encouraged the development of a unique character for American air power by spreading his defiant sense of independence and a willingness to espouse doctrines heretical to the War Department.[92] During WWI, Mitchell's early call for the independence of the air arm clearly influenced the thinking of the somewhat malleable Edgar Gorrell.[93] In the interwar period through WWII, nearly every major air power figure – Hap Arnold, Ira Eaker, Carl Spaatz to name but a few – were infected with or influenced by Mitchell's sense of defiance.[94] Mitchell's court martial was a significant emotional event for the Air Service that added to the "persecution complex" of airmen. The negative example of the court martial also had the important effect of encouraging greater political savvy in later air power leaders, a savvy necessary to make the new doctrine stick.[95]

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[90] William Mitchell, *Skyways: A Book on Modern Aeronautics* (Philadelphia: Lippincott, 1930), 255-256.
[91] See Phillip S. Meilinger, "Introduction," in Phillip S. Meilinger, ed., *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell AFB, AL: Air University Press, 1997), xi.
[92] See Emme, "Technological Change and Western Military Thought," 12. Unlike Mason Patrick, who "advocated airpower with moderation, reason rather than emotion," Mitchell's public stunts hardened the Army to an autonomous Air Corps, further driving the wedge that came to separate the two interdependent organizations. Tate, *The Army and Its Air Corps*, 131.
[93] Williams, "The Shank of the Drill," 403. See also Tate, *The Army and Its Air Corps*, 44-45.
[94] Cooke, *Billy Mitchell*, 283; Holley, "Reflections on the Search for Airpower Theory," 582-583. Arnold later wrote that, even if Mitchell had won his battle with the Army and Navy, his dreams for air power would not have been possible until the late 1930's when a combination of technology and foreign threats combined in the realization of air power's potential. Arnold, *Global Mission*, 158.
[95] See Tate, *The Army and Its Air Corps*, 191. On the increasing political savvy of American air power proponents, see Underwood, *Wings of Democracy*, 3-5. On Mitchell's lasting influence, see Maj Alexander P. DeSeversky, "America's Half-Honored Prophet: An Examination of Billy Mitchell's Public Record Together With an Appreciation," December 1942. AFHRA file no. 146.001-16. See also Col. William R.

Perhaps the single most important influence Billy Mitchell had in the formulation of American air power doctrine was in his sway over the future instructors at the Air Corps Tactical School, the most important of the many organizations that contributed to the development of interwar air power doctrine, especially after the school moved from Langley Field in Virginia to Maxwell Field in Montgomery, Alabama in 1931.[96] As one former instructor at the school proclaimed, the faculty at Maxwell "struggled against, and broke, the chain of mental inertia which binds all established organisms—and military organisms in particular ... the natural tendency among military men to perpetuate the concepts, tactics, and equipment that have proved reasonably satisfactory in the past, and to concentrate on improvement in the technical characteristics of existing weapons."[97] As a clearinghouse for air power ideas, the Air Corps Tactical School built the intellectual foundations of the American air power doctrine of precision bombardment.

During the school's formative years, two distinguished Air Service officers, Thomas DeW. Milling and William C. Sherman, were particularly important in promoting strategic bombardment and in developing the underlying principles of American air power.[98] Milling was the organizational force behind the establishment of

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Yancey, "A Look at 'Billy' Mitchell in 1953," Maxwell AFB, AL: Air War College, September 1953. AFHRA file no. K239.0422-4.

[96] The Air Service Field Officer's School at Langley Field, Virginia was established in 1920, concurrent with the recognition of the Air Service as a combatant arm of the Army. In 1922, the school was renamed the Air Service Tactical School and later, with the Air Corps Act of 1926, the Air Corps Tactical School. The best single history of the Air Corps Tactical School is Finney, *History of the Air Corps Tactical School, 1920-1940*. See also McFarland, *America's Pursuit of Precision Bombing*, 89-99; Faber, "Interwar US Army Aviation and the Air Corps Tactical School" in Meilinger, ed., *The Paths of Heaven*; and Thomas A. Fabyanic, *A Critique of United States War Planning, 1941-1944*, unpublished dissertation, St. Louis University, 1973, 1-48. On Mitchell's impact on the school, see Flugel, *United States Air Power Doctrine*, 94-97 and 254-258; Clodfelter, "Molding Airpower Convictions," 108; Hurley, 112; and Scott D. West, *Warden and the Air Corps Tactical School: Déjà vu*? (Maxwell AFB, AL: School of Advanced Airpower Studies, October 1999).

[97] Hansell, *The Air Plan That Defeated Hitler*, 30-31.

[98] Faber, "Interwar US Army Aviation and the Air Corps Tactical School," 214-215. On the relationship between Milling and Sherman and their activities during the early years of the school, see Wray R.

the school; Sherman was its intellectual founder. Milling, who served as Billy Mitchell's successor as Chief of the Air Service, First Army during the war and became the school's first Officer in Charge, took on the daunting task of setting up the Air Service Field Officers' School at Langley Field in 1920 in the midst of the post-war demobilization.[99] Sherman, who had worked with Gorrell on lessons learned from the war, created the curriculum for the new school; his first textbook, written in 1921 for the course *Employment of the Combined Air Force,* became the Army-approved air power doctrinal manual, *Training Regulation 440-15, Air Tactics* in 1926.[100]

Sherman's later work, *Air Warfare*, laid the foundations for later theories of precision bombardment of an enemy's economic infrastructure.[101] *Air Warfare* highlighted the effects of the limited bombing campaigns of World War I: "the moral effect of day bombing was all out of proportion to the small number of airplanes employed and the small weight of metal and explosive they could discharge in one 'broadside'."[102] Pointing out the specialization of modern industrial economies that made

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Johnson's "Introduction" in William C. Sherman, *Air Warfare*, reprint of the 1926 edition (Maxwell AFB, AL: Air University Press, 2002), iii-xviii. Milling and Sherman were both active participants in the sinking of the *Ostriesland*. Sherman, *Air Warfare*, xiv. See also Flugel, *United States Air Power Doctrine*, 97.

[99] Finney, *History of the Air Corps Tactical School*, 9-10. On the difficulties the school faced in formulating "principles of air strategy from scratch," see T.D. Milling, "Tactics of the Air Force in War," lecture at the Army War College, 27 November 1923, 9. AFHRA file no. 248.211-65N. See also Thomas Milling, "The Air Service Tactical School," Langley Field, VA: May 1924. AFHRA file no. 245.01-3.

[100] *Training Regulations No. 440-15: Fundamental Principles for the Employment of the Air Service* (Washington, D.C.: War Department, 26 January 1926). AFHRA file no. 248.11-65A. On the history and contents of *TR 440-15*, see Flugel, *United States Air Power Doctrine*, 173-182. See also Finney, History of the Air Corps Tactical School, 20; Greer, *The Development of Air Doctrine*, 40-41; and Craven and Cate, 1, 40-41.

[101] Flugel, *United States Air Power Doctrine*, 196-198. Sherman was an admirer of Clausewitz, frequently mentioning his dictums on uncertainty and the unavoidably political nature of warfare. See especially Sherman, *Air Warfare*, 33, 90-91, and 195.

[102] Sherman, *Air Warfare*, 188.

them vulnerable to strategic attack, Sherman's book gave a first glimpse of the Air Corps Tactical School's signature "industrial web" theory of the 1930's.[103]

Sherman acknowledged the difficulty of quantifying the effects of strategic bombing and the indeterminate nature of war. His book nevertheless exaggerated the certainty with which bombs could be delivered on target, especially given the technological limits of the day.[104] "An estimate of the probable line of flight of the bomb is no longer a mere guess," wrote Sherman. "Bombs have been studied and experimented with, until their trajectories are now uniform, and accurately predictable."[105] The publication of *Air Warfare* in 1926 thus represented a milestone in American air power theory, both in its contribution toward the choice of strategic bombardment over pursuit and close air support of ground forces, as well as in the mechanism and determinism that technological innovation inspired in the mind of William Sherman.

Strategic bombing was not an unchallenged concept in the 1920's, however, even at the Air Corps Tactical School. Advocates of pursuit and attack aviation pointed to international laws prohibiting the bombing of population centers, to the technological disadvantages of the bomber relative to pursuit, and the isolated strategic context of the United States and the subordinate position of the Air Corps within the Army in their arguments for a more balanced air power doctrine.[106] A confluence of events in 1929-

[103] Sherman, *Air Warfare*, 195-198.
[104] Sherman, *Air Warfare*, 90-91 and 198.
[105] Sherman goes on to provide a table that gives the precise destructive effects of different size bombs in terms of crater diameters, crater depths, and "Diameter of Danger Space to Personnel." Sherman, *Air Warfare*, 180-181.
[106] Greer, *The Development of Air Doctrine*, 66-67, and Tate, *The Army and Its Air Corps*, 161-162. The two most active advocates of attack and pursuit aviation were George C. Kenney who taught the Attack course from 1926 to 1929, and Claire L. Chennault who taught the Pursuit course from 1932 to 1936. Laurence Kuter, a member of the "bomber mafia" at the school in the 1930's, later claimed that there was a retreat from the strategic bombing concept prior to 1933 because of "the influence of the conventional military mind." Kuter, "Air Power – The American Concept," 21.

1931 unleashed a wave of positive reinforcement for the idea of precision bombardment: Army authorization for procurement of the much-improved Boeing B-9 and the Martin B-10 twin-engine bombers; the liberating move of the Air Corps Tactical School from Langley to Maxwell; the departure of pursuit advocate George Kenney from the school's faculty; and the arrival of the first of the true bomber zealots, Ken Walker and Donald Wilson.[107] By 1931, the school's manuals for bombardment aviation openly declared Bombardment aviation as "the basic arm of the air force," advocating daylight bombing to ensure the necessary precision to destroy "vital objectives."[108] The school's adoption of the motto "Proficimus More Irrententi" (We Make Progress Unhindered by Custom) in 1929 further demonstrated the growing sense of independence and willingness to deviate from more conservative doctrinal lines.[109]

Walker's primary contribution as head of the Bombardment Section from 1929-1934 was his promotion of the Douhetan dictum (later repeated by Stanley Baldwin) that "the bomber will always get through" and its corollary that the best way to defeat an opposing air force was by aggressively bombing airfields, supply depots, and manufacturing centers.[110] Walker, along with Harold George, Haywood Hansell, and Grandison Gardiner, developed an extensive "Theory of Probabilities," borrowed primarily from the Field and Coastal Artillery, to solve more systematically the problems

[107] Greer, *The Development of Air Doctrine*, 66. See also Richard K. Muller, "Close Air Support: The German, British, and American Experiences, 1918-1941," in Murray and Millett, eds., *Military Innovation in the Interwar Period*, 172-175.
[108] Air Corps Tactical School, *Bombardment Aviation* (Langley Field, VA: February 1931). AFHRA file no. 248.1-1-9. See also Kenneth N. Walker, "Project for Field Manual's Bombardment Section," 24 September 1932 (Walker's comments on a proposed draft for the Bombardment course). AFHRA file no. 248.211-13.
[109] West, *Warden and the Air Corps Tactical School*, 26.
[110] "A well-organized, well planned, and well-flown air force attack will constitute an offensive that cannot be stopped." Quoted in Martha Byrd, *Kenneth N. Walker: Airpower's Untempered Crusader* (Maxwell AFB, AL: Air University Press, 1997), 36. See also Kenneth N. Walker, "Bombardment Aviation:

of weapons selection and bombing effects. Although thoughtfully reasoned and empirically tested, these theories were applied in an overly simplistic way, mechanically translating probabilities into certainties.[111] But as even the *Bombardment* course text for 1935 noted, the causes of bombing error were both *determinate* – those that could be corrected through training and experience – and *indeterminate* – those inestimable errors caused by mechanical malfunction of release mechanisms, human errors in coordination between pilot and bombardier, or variations in weather conditions. The second category of error, despite Walker's understandable desire to rationalize the process, thwarted precise estimates of the probability of accurate bombing.[112] Furthermore, ACTS texts calculated these probabilities for single bomb sightings, and not for salvos of bombs or formation bombing. As the post-World War II Strategic Bombing Survey pointed out, however, only a portion of dispersed bomb patterns from salvo or formation bombing could fall on small precision targets. Additionally, flying in formation restricted freedom of maneuver, which further decreased bombing accuracy.[113]

Bulwark of National Defense," *U.S. Air Services* (August 1933) in *ibid.*, 179-190. On Walker's contribution to precision air power, see McFarland, *America's Pursuit of Precision Bombardment*, 84-88.

[111] On the ACTS belief that "through statistical methods and probability theory, the important aspects of bombing could be quantified and their effects against the enemy predicted," see Williamson Murray, "Strategic Bombing: The British, American, and German Experiences," in Murray and Millett, eds., *Military Innovation in the Interwar Period*, 99.

[112] See *Bombardment* (text for Bombardment course at ACTS), November 1935, 49-75 and *Appendix to Text: Theoretic Bombing Probabilities*, July 1935. AFHRA file no. 248.101-9. The entire list of indeterminate errors included measurement errors from variation or fluctuation of instruments, mechanical errors in release mechanisms, minor deviations in computed trajectories, human errors in sighting or in coordination between pilot and bombardier, and variations in environmental conditions like the weather. Having described these intedeterminate errors, the text went on to mathematically develop a Law of Errors to correct for this indeterminacy. Hap Arnold's reference to these *Tables of Bombing Probability* in an address to the Army's Command and General Staff School in 1939 demonstrates not only their longevity, but also the faith the Air Corps put in their predicted results. See H.H. Arnold, address at the Army Command and General Staff School, Ft. Leavenworth, KS, 7 February 1939, 13-14. AFHRA file no. 248.211-22. See also Hansell, *The Air Plan that Defeated Hitler*, 16-17.

[113] *The United States Strategic Bombing Survey: Summary Report (European War) (Pacific War)*, reprint of 1945 edition (Maxwell AFB, AL: Air University Press, 1987), 13. See also Fabyanic, *A Critique of United States Air War Planning*, 36-40.

While Walker provided the untempered enthusiasm for bombardment, Donald Wilson's primary contribution to the intellectual foundations established by Sherman was in the process of target selection.[114] Wilson later complained that Mitchell "made no attempt to deal in useful specifics " and that Douhet "lacked a scientific approach to target selection, and seemingly had no faith in precision bombing. Thus he never seemed to recognize the small important keys essential to the success of whole large systems."[115] As a former railroad man, Wilson saw the potential for disproportionately large results through the precise destruction of "bottleneck" targets in an opponent's industrial infrastructure: "I had seen during my surveying occupation how railroad traffic could be halted by a single washed-out bridge."[116]

Promulgated by Wilson, the full-fledged theory of the "industrial web" emerged at ACTS during the 1933-34 academic year.[117] ACTS instructors equated modern warfare with economic competition between industrialized nations.[118] Just as the economic weakness of Italy in the post-World War I period had impressed Douhet, the Depression convinced ACTS theorists of the economic vulnerability of the modern nation.[119] The interdependent components of a modern, industrialized nation were both its source of strength, as well as of weakness: "[T]he amount of destruction required would be small in comparison with the magnitude of the results" to be achieved by

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[114] See Donald Wilson, *Wooing Peponi: My Odyssey Thru Many Years* (Monterey, CA: Angel Press, 1973) and Wilson, "Origin of a Theory for Air Strategy," 19-25.
[115] Wilson, "Origin of a Theory of Air Strategy," 22.
[116] Wilson, *Wooing Peponi*, 238.
[117] Wilson, *Wooing Peponi*, 237, and "Origin of a Theory for Air Strategy," 19. See also Finney, 65-66.
[118] Greer, *The Development of Air Doctrine in the Army Air Arm,* 128.
[119] Hurley, 76-77. See also Rinaldi, "Complexity Theory and Airpower," 269.

precisely targeting key nodes or linkages between the interdependent parts of the national economy.[120] As Wilson's fellow instructor Muir Fairchild explained in 1939:

> "[M]odern warfare places an enormous load upon the economic system of a nation, which increases its sensitivity to attack manifold. Certainly a breakdown in any part of this complex, interlocked organization, must seriously influence the conduct of war by that nation and greatly interfere with the social welfare and morale of its nationals."[121]

The paucity of military budgets during the Depression forced air planners to seek efficiency and economy of force in winning wars.[122] In the eyes of the bomber mafia at ACTS, precision bombing against critical nodes of an enemy's industrial infrastructure was vastly more efficient than the attrition-oriented strategies advocated by the Army and Navy. Furthermore, if pursuit or fighter airplanes were of little consequence to the strategic air battle, there was no sense in wasting precious resources on their procurement or even on the development of pursuit and attack doctrine. As Claire Chennault grumbled,

> During the depression years Air Corps funds were slashed so drastically that there was hardly enough money to buy gas for the four hours a month in the air required to collect flying pay. The battle between the bomber radicals and the handful of fighter advocates grew more bitter as the competition for money got stiffer. Bomber boys were already thinking about the then fantastic costs of the first four-engine Boeing B-17's. Every nickel spent on fighters seemed sheer waste to them. ... The office of the Chief of the Air Corps adopted the slogan, "Fighters are obsolete," and funds for their development and procurement were greatly reduced.[123]

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[120] "Air Force Objectives," 1934-1935, 5. Quoted in Rinaldi, "Complexity Theory and Airpower," 268.
[121] Muir S. Fairchild, "National Economic Structures," ACTS lecture, April 1939. Quoted in Rinaldi, "Complexity Theory and Airpower," 267. In a lecture delivered in 1939, Frank Andrews used the analogy of a precision watch: "Modern nations are as sensitive as a precision instrument. If you damage one vital part of a watch, the whole ceases to function." Frank M. Andrews, "Modern Air Power" (address before the National Aeronautic Association, St. Louis Missouri, 16 January 1939), 8. AFHRA file no. 248.211-20.
[122] McFarland, *America's Pursuit of Precision Bombing*, 92.
[123] Chennault, *Way of a Fighter*, 26.

With little money for research and development or empirical testing, doctrine based on unproven assumptions was the best the Air Corps and its Tactical School could offer.

The most difficult, and in the end unsatisfactorily solved, part of the problem proved to be the correct identification of these targeted vital links.[124] Lacking operational experience and adequate economic intelligence on foreign nations, the faculty at the Air Corps Tactical School instead turned to theoretical discussions of air attacks against the "national economic structure" of the United States.[125] This "mirror imaging" also added weight to the argument for an independent strategic bombing doctrine by heightening the public sense of vulnerability to air power.

A number of other pathologies beyond mirror imaging also afflicted the faculty at the Air Corps Tactical School. The faculty at ACTS, working under the assumption that war could be scientifically managed, underestimated the potential of defensive strategies and technologies and the nonlinear interaction of competing wills. Their theories also overplayed the psychological impacts of aerial destruction, making it appear that modern states were universally brittle, rather than flexible and adaptive.[126] Stephen Rinaldi, drawing from the paradigm of complexity theory, adds yet another criticism of the Air Corps Tactical School: instructors saw the effects of bombing as linear and cumulative, inappropriately applying the principle of superposition to aerial bombardment. For

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[124] As Haywood Hansell later pointed out, the targeting of specific links in economic structures was "beyond the competence of the school. Strategic air intelligence concerning major world powers would require an organization and a competence of considerable scope and complexity." Hansell, *The Air Plan that Defeated Hitler*, 48.

[125] For an early example of ACTS' mirror imaging see George H. Peabody, "What Damage Could Any Nation or Combination of Nations do the U.S. From the Air if War Were Suddenly Declared?" Langley Field, VA, 3 May 1929. AFHRA file no. 248.211-30B. See also Muir S. Fairchild, "National Economic Structure," Maxwell Field, AL, 1939-1940. AFHRA file no. 168.7001-31. Fairchild's cover letter on the report addressed to General Arnold concludes: "The study shows that 100 bombs (or perhaps fewer) accurately placed in our vital industrial area would instantly reduce us to the status of a second or third rate power, unable to equip or maintain our armed forces – perhaps even unable to fully sustain our civilian population."

ACTS theorists, the destructive effects of bombardment were merely cumulative over time, and not a nonlinear function of the enemy's ability to adapt and repair.[127]

The most egregious of all of ACTS' theoretical errors was the tendency to conflate the tactical efficiency of precision bombing with strategic effectiveness. Theorists at the school concentrated on the destructive means of air warfare, rather than the ultimate ends, reducing the complexities of military strategy to a problem in air targeting.[128] When lecturers concluded that the art of air strategy was in choosing the objective, they had in mind specific panacea targets, not ultimate political purposes.[129] I. B. Holley contends that the obsession with tactical precision at the expense of strategic purposes was due in part to instructors' lack of broad educational backgrounds; the focus at the school was consequently on more narrow technical training, not education.[130] The faculty at the Air Corps Tactical School was both an important positive influence on the development of an American theory of air warfare, as well as a negative source of the the overly mechanistic approach to air power that has carried through in the United States Air Force to the current day.

The Tactical School had increasing influence over policies and doctrine throughout the 1930's and their theories hardened into Air Corps dogma. The Air Corps Board, whose primary official function was the formulation of uniform tactical doctrines for all types of air units, moved to Maxwell in January 1934 and drew on ACTS

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[126] Faber, "Interwar US Army Aviation and the Air Corps Tactical School," 220-221.
[127] Rinaldi, "Complexity Theory and Airpower," 271-272. For yet another critique of ACTS thinking, see Fabyanic, *A Critique of United States Air War Planning*, 45-47.
[128] MacIsaac, "Voices from the Central Blue," 635.
[129] Hansell notes that the Air Corps was more in line with the thinking of Helmuth von Moltke than Clausewitz. "[T]he idea of frequent change in military objectives brought about by politicians would have brought misgivings and opposition" from the Air Corps Tactical School faculty. Hansell, *The Air Plan That Defeated Hitler*, 38-40.

instructors as members and advisors.[131] In 1934, several ACTS instructors, including Wilson, Walker, and Harold George, testified before the Howell Commission charged by President Roosevelt to evaluate civil and military aviation.[132] In 1935, the school submitted formal proposals for doctrine for the newly organized GHQ Air Force to the Army's spokesman on the Howell Commission, Brigadier General Kilbourne Assistant Chief of Staff, War Plans Division.[133] The influence of ACTS over the Air Corps was a function not only of active instructors, but also of a growing body of ACTS graduates. Whereas only fifteen percent of air officers graduated from the school from 1921-1930, sixty-five percent of air officers were graduates during the period 1936-1940. Of the 1091 ACTS graduates, 261 became general officers in WWII.[134]

The Social and Political Impetus for Precision Bombing

American air power doctrine cannot be understood separate from the intellectual, social, and political context from which it emerged.[135] American airmen conceived their doctrine in reaction to the wave of revulsion following the social catastrophe of World War I. Airmen sold precision air power to the American public as purer than ground war, recalling the days when battle was valorous and chivalric.[136] For the Air Service,

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[130] Holley, "Reflections on the Search for Airpower Theory," 587. See also McFarland, *America's Pursuit of Precision Bombardment*, 91.
[131] Finney, *History of the Air Corps Tactical School*, 28-32. See also Faber, "Interwar US Army Aviation and the Air Corps Tactical School," 200-203.
[132] Hansell, *The Air Plan that Defeated Hitler*, 24-30. See also ACTS Howell Commission Testimony. AFHRA file no. 248.211-16.
[133] See "A Study of Proposed Air Corps Doctrine," Maxwell Field, AL: 31 January 1935. AFHRA file no. 248.211-65.
[134] Faber, "Interwar US Army Aviation and the Air Corps Tactical School," 211-212. See also Finney, *History of the Air Corps Tactical School*, 41-43.
[135] Overy, "Introduction," in Cox and Gray, x.
[136] Joseph J. Corn, *The Winged Gospel* (New York: Oxford University Press, 1983), 11.

promoting air power as an alternative to the brutality of the Western front was both a measure of humanity as well as self-interest.[137]

Unlike Douhet, who advocated avoiding the horrors of trench warfare by inducing quicker but more effective horrors against populations, American airmen proposed a cleaner solution – striking precisely at the vital material links of an enemy nation. Attacking the popular will, the method of Trenchard and Douhet, did not require precision. Inaccuracy, in fact, was better for terrorizing a population into capitulation. Physical destruction of vital targets on the other hand, demanded discrimination and precision. Billy Mitchell, a model incarnation of the American spirit of progressivism, claimed that air power used discriminately could thus "result in a diminished loss of life and treasure and will thus be a distinct benefit to civilization."[138] The bomber as an instrument of change could prevent foreign invasion by sea, and if necessary, could preclude the messier aspects of offensive warfare.[139]

American air theorists were well aware of international norms against indiscriminate bombardment like those promulgated at the Hague Conferences of 1899 and 1907 and proposed as "Air Warfare Rules" in 1923.[140] As William Sherman carefully pointed out, "To the student of air warfare of the future, the status of air bombardment in international law is a matter of profound concern, since it may have far

[137] Weigley, *The American Way of War*, 224. McFarland, *America's Pursuit of Precision Bombing*, 26.
[138] Quoted in Clodfelter, "Molding Airpower Convictions," 90. See also Mitchell, *Winged Defense*, 16 and *Skyways*, 262.
[139] Clodfelter, "Molding Airpower Convictions," 89-90.
[140] The first Hague Conference in 1899 prohibited "the attack or bombardment of towns, villages, habitations or buildings which are not defended." The second in 1907 added the words "by any means whatever" to extend this prohibition to aerial warfare. The Air Warfare Rules proposed in 1923, never ratified yet considered authoritative, extended the prohibition against indiscriminate attacks against civilian populations, but substituted the notion of military objective for undefended places. See Hamilton De Saussure, "International Law and Strategic Bombing," *Air University Review* 5/3 (Summer 1952), 22-34. See also W. Hays Parks, "Air War and the Law of War," in Boog, ed., *The Conduct of the Air War in the Second World War*, 310-372.

reaching effects on the strategical employment of the air force."[141] American airmen faced a legal and ethical dilemma – the bomber was their most promising strategic instrument, but using it meant violating international norms for ethical conduct in war.[142] The Army and Navy also noted the airman's dilemma and used this weapon of conscience to their advantage in the interservice struggle for resources.[143] In November 1918, for example, Secretary of War Newton Baker very publicly told the Army Chief of Staff General Peyton March to warn the Air Service against conducting any form of "promiscuous bombing."[144]

Precision bombing against material targets offered a solution to this dilemma. Despite the Hague rules forbidding attack against civilian targets, Mitchell suggested manufacturing centers as legitimate military objects; the effects promised by destruction of vital industrial targets better fit American sensibility than directly attacking the morale of the enemy population.[145] Human reactions to bombing were too difficult to measure anyway, as Donald Wilson pointed out; it would be better "to choose physical necessities for the principal objectives of the air force."[146] Bombing industrial facilities simplified the targeting equation by taking out the unsavory and unquantifiable variable of civilian morale.[147]

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[141] Sherman, *Air Warfare*, 190.
[142] On the ethical dilemmas that strategic bombing presented for interwar air theorists, see Ward Thomas, *The Ethics of Destruction: Norms and Force in International Relations* (Ithaca, NY: Cornell University Press, 2001), 87-146. See also Edward C. Holland, *Fighting with a Conscience: The Effects of an American Sense of Morality on the Evolution of Strategic Bombing Campaigns* (Maxwell AFB, AL: Air University Press, 1992), 9-14.
[143] See Weigley, *The American Way of War*, 237 (and note 33).
[144] Clodfelter, "Molding Airpower Convictions," 87.
[145] Flugel, *United States Air Power Doctrine*, 129. Sherry, *The Rise of American Air Power*, 58.
[146] Quoted in Flugel, *United States Air Power Doctrine*, 247.
[147] Conrad C. Crane, *Bombs, Cities and Civilians: American Airpower Strategy in World War II* (Lawrence, KS: University Press of Kansas, 1993), 20-22.

Precision bombing therefore offered the moral high ground. When the high ground of discrimination proved too great a technological reach even for the airplane, airmen fell back on strategic bombers as a means for reprisal.[148] As the 1926 Bombardment manual stated, "The bombing of political centers is prohibited by the laws of warfare. However, since they are the nerve centers of the nation, they are apt to be important targets for bombardment in reprisal for attacks made by the enemy on such centers in our own country, especially since they are apt to contain important factories of stores of war material."[149]

The prohibitions proposed at the Geneva Disarmament Conference in 1932 and the nineteenth assembly of the League in 1938, although increasingly ineffectual in practice, reflected enduring international opinion against aerial bombing. Bombing campaigns against defenseless civilians in Manchuria by the Japanese, in Ethiopia by Italy, and in the Spanish Civil War within Europe proper, increased popular aversion to strategic bombing.[150] "Bombardment," wrote Hap Arnold, "came to be classed in the public mind as akin to the criminal in warfare."[151] Roosevelt's call in September 1939 for all combatants to restrain from targeting civilian populations in unfortified cities demonstrated the American distaste for indiscriminate bombing.[152] Before Pearl Harbor sparked the ire of America, the Air Corps could only sell the strategic bombing mission by playing to the traditional American respect for technology and marksmanship, portraying high-altitude precision daylight bombing as more efficient, discriminate, and

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148 McFarland, *America's Pursuit of Precision Bombing*, 81-83.
149 Air Corps Tactical School, *Bombardment* (Langley Field, VA: 1926), 63-64. AFHRA file no. 248.101-9.
150 Emme, "Technological Change and Western Military Thought," 16.
151 Arnold, *Global Mission*, 159.
152 US Department of State, *Foreign Relations of the United States, 1939*, vol. 1(Washington: 1956), 541-542.

therefore, more humane.[153] Even after the events of the Second World War showed discrimination and restraint untenable, American airmen clung to the high ground of precision bombing.[154] "[W]e should never allow the history of this war," declared General Ira Eaker, "to convict us of throwing the strategic bomber against the man in the street."[155]

In addition to the ethical predicament strategic bombing presented, airmen before the war also faced a political and geostrategic dilemma. American airmen confronted the challenge of squaring two diametrically opposed concepts – a traditionally defensive U.S. strategic policy and an offensive air doctrine.[156] During the interwar period, the disarmament conferences dominated the international political scene and the watchwords of the day were normalcy and isolationism.[157] The strategic context of the United States suggested the defensive mission of coastal patrol as the most favorable for the

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[153] As Alexander de Seversky noted, "...the haphazard destruction of cities – sheer blows at morale – are costly and wasteful in relation to the tactical results obtained. ...the will to resist can be broken in a people only by destroying effectively the essentials of their lives – the supply of food, shelter, light, water, sanitation, and the rest. This clearly demands *precision bombing* rather than random bombing." Alexander P. de Seversky, *Victory Through Air Power* (New York: Simon and Schuster, 1942), 145-147. Airmen, both before and after WWII, frequently added the traditional American respect for marksmanship to their list of arguments for precision strategic bombing. See "The Strategic Bomber," 95. See also Craven and Cate, 1, 597-598.

[154] McFarland, *America's Pursuit of Precision Bombing*, 185. 8th AF records kept during the war reflected targets as "a city area;" after the war, the same targets were changed to "marshalling yards" or "port" or "industrial areas" in the official 8th AF statistical summary. Richard G. Davis, "German Railyards and Cities: U.S. Bombing Policy 1944-1945," *Air Power History* 42 (Summer 1995), 51. On American morality and precision bombing, see especially "Suggested Reply to Letters Questioning Humanitarian Aspects of Air Force," written by a member of General Arnold's staff during the war in Crane, *Bombs, Cities and Civilians*, 163-164. As Ward Thomas notes, the norm against bombing civilian populations was a "convention-dependent norm" based heavily upon reciprocity. As combatants increasingly abandoned this norm beginning with British and German exchanges in 1940 and 1941, the norm became easier to violate under the guise of "military necessity." "...late in the war the USAAF was willing to bomb just as destructively as the RAF, as long as it could be claimed that missions were directed at legitimate targets." Thomas, *The Ethics of Destruction*, 125 and 134. On "The Dynamics of Escalation," see Sherry, *The Rise of American Air Power*, 147-176.

[155] Quoted in Ronald Schaffer, "American Military Ethics in World War II: The Bombing of German Civilians," *The Journal of American History* 67/2 (September 1980), 318.

[156] "The Strategic Bomber," 94.

[157] Craven and Cate, 1, 18. Sherry, *The Rise of American Air Power*, 33-38.

procurement of new bombers.[158] Airmen at the Air Corps Tactical School highlighted the defensive role of the bomber: "[T]he bombardment airplane in the hands of the United States," lectured Ken Walker, "is purely a defensive weapon."[159] Along these same lines, Hap Arnold promoted air refueling as a way to extend the range of transports (not bombers) to mask the offensive nature of Air Corps doctrine; Benjamin Foulois depicted the autopilot as a means to relieve fatigued pilots, averting attention from its intended purpose of providing a stable platform for more accurate bombing.[160]

But a strictly defensive slant had negative implications for an air force in search of an independent strategic mission. Long-range bombers were expensive and unnecessary if the primary air mission was coastal defense. In 1936, therefore, the Army War Plans Division proposed to limit the range of bombers to fit the defensive roles assigned to the Air Corps.[161] If the Air Corps needed the 4-engine B-17 for its strategic doctrine instead of the shorter ranged B-18 the Army preferred, airmen needed a better rationale than coastal defense.

With an increasingly threatening international environment and the technological capability for greater range, the Air Corps extended coastal defense to hemispheric defense as the logical role for air power.[162] As Frank Andrews, who campaigned hard

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[158] Arnold, *Global Mission*, 157. Billy Mitchell, well aware of the power of public sentiment, titled his book *Winged Defense* (as opposed to *Winged Offense*) to portray the airplane as an instrument of peace. Other Mitchell titles are equally as telling: *Our Air Force, The Keystone of National Defense*; "Airplanes in National Defense;" "Our Problem of National Defense;" "Crushing America by Air;" and "The Next War – What About Our National Defense." James Eastman, "The Development of the Big Bombers," *Aerospace Historian* 25 (Winter 1978), 212. See also Clodfelter, "Molding Airpower Convictions," 100-105.
[159] Walker, "Bombardment Aviation – Bulwark of National Defense," in Byrd, *Kenneth C. Walker*, 189.
[160] McFarland, *The American Pursuit of Precision Bombing*, 38.
[161] Tate, *The Army and Its Air Corps*, 167. Eastman, "The Development of Big Bombers," 214-215.
[162] "When it comes to a squabble over foreign influence in some remote part of this hemisphere, and we find ourselves with a great fleet of short range airplanes which can do no more than move to the scene of the local action and perhaps crush the foreign injection of military and civil power, while at the same time the foreign nation is prepared to attack us at home from beyond the reach of our aircraft, then despite our

against Army and Navy moves to limit the range of the bomber, put it: "We need AIR POWER. In building up our national defenses we are saying in unmistakable language: HANDS OFF THE WESTERN HEMISPHERE – AMERICA IS FOR AMERICANS."[163] The Air Corps' promotion of hemispheric defense fit well with the Roosevelt Administration's "Good Neighbor Policy" and their reinterpretation of the Monroe Doctrine. In October 1938, the Air Corps Board completed its study, "Air Corps Mission Under the Monroe Doctrine" that described the primary role of the Air Corps as countering hostile nations trying to establish themselves in the Western hemisphere.[164] "Goodwill" flights of B-17s in 1938 and a lone B-15 in 1939 to South America dramatically demonstrated the potential of this new mission.[165] American air power, although purportedly fashioned with a defensive geostrategic context in mind, nevertheless successfully acquired the means – long-range heavy bombers – to carry out an offensively oriented doctrine.

The Coevolution of Doctrine and Technology

Air power is unavoidably a technological affair. Just as American air doctrine was contingent on the social and political context, it was also contingent on the availability of certain technologies. The coevolution of technology and doctrine was yet

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7,000 to 10,000 short range aircraft we are licked before we begin." Donald Wilson, "Long Range Airplane Development," November 1938, 2. AFHRA file no. 248.211-17.

[163] Andrews, "Modern Air Power," 15.

[164] Craven and Cate, 1, 50. See also Eastman, "The Development of Big Bombers," 217.

[165] Eastman, "The Development of Big Bombers," 216. See also Maurer, *Aviation in the U.S. Army*, 355-360.

another ultimately unquantifiable, yet profoundly influential, variable in the development of American precision air power prior to World War II.[166]

The doctrine of precision bombing that blossomed in full flower in the 1930's depended on a string of technological innovations: an airplane large enough to deliver an adequate bomb load, yet could fly fast enough and high enough to avoid enemy defenses (or be sufficiently armed to fight its way through these defenses); equipment to navigate and find designated precision targets, even in marginal weather; the ordnance to cause the desired effects on these vital targets; and a bombsight accurate enough to reliably hit the target from high altitudes. Although each of these technological capabilities was essential to high-altitude precision bombing, the long-range bomber and the precision bombsight were of critical importance.

During the interwar period, technological development in aviation lagged behind its theoretical potential – air power theory and even published doctrine generally outpaced existing technology. Instructors at the Air Corps Tactical School worked out their bombing schema in the late 1920's and early 1930's before the appearance of the B-17 and without knowledge of the Norden XV bombsight. Airmen at the school believed, however, "that if the advantages of precision bombing could be established in theory, American ingenuity and inventiveness would provide the means for making such bombing possible in practice."[167]

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[166] On the "...complex interaction of unpredictably swift technical change commingling with the major political forces determining the complicated course of international events in the interwar period," see especially Emme, "Technological Change and Western Military Thought, 1914-1945."
[167] Laurence Kuter quoted in McFarland, *America's Pursuit of Precision Bombing*, 90.

In the early 1920's, the technology of the pursuit or fighter plane was superior to that of the bomber, especially in the vital characteristics of speed and maneuverability.[168] The first American attempt at a large bomber, the Barling bomber, was an unmitigated failure. The lumbering bomber, a triplane powered by six Liberty engines with a gross weight of 42,000 pounds, could not even fly high enough to cross the Appalachian Mountains and therefore was never produced in quantity.[169]

New air doctrines pulled aviation technology forward in the late 1920's and early 1930's. The search for more capable bombers inspired developments that included monoplane designs, all-metal construction, retractable landing gear, and increases in operating range and altitude. Technological innovations also pushed air power doctrine. Civil aviation's increasing emphasis on large multi-engined aircraft with greater carrying capacity also encouraged the doctrine of long-range bombing.[170]

Despite these advances, the Keystone B-3A delivered to the Air Corps in 1930 was still a biplane design whose speed and range were little improved over earlier bombers. In the same year, however, the Air Corps authorized the procurement of the Boeing B-9 and the Martin B-10, twin-engine bombers with much improved operating characteristics.[171] The B-10's delivered to the Air Corps in 1932, with their sleek all-metal design and an operating speed of 207 miles per hour, service ceiling of 21,000 feet,

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168 On the development of bomber technology in the interwar period see Jean H. Dubuque and Robert F. Gleckner, *The Development of the Heavy Bomber, 1918-1944*, USAF Historical Study No. 6 (1951). AFHRA reel no. K1001; "The Strategic Bomber;" and Eastman, "The Development of Big Bombers." For a contemporary account of the characteristics required by the various types of airplanes, see *Training Regulations No. 440-15: Fundamental Principles for the Employment of the Air Service* (Washington, D.C.: War Department, 26 January 1926), 2-5 ("Aircraft Characteristics"). AFHRA file no. 248.11-65A.

169 Craven and Cate, 6, 202-203 and 1, 58.

170 David E. Johnson, *Fast Tanks and Heavy Bombers: Innovation in the United States Army, 1917-1945* (Ithaca, NY: Cornell University Press, 1998), 91. See also Arnold, *Global Mission*, 127 and Craven and Cate, 1, 55-56.

and range of 900 miles, could outrun existing pursuit aircraft.[172] Bombing advocates now had the technology to back up at least one tenet of their doctrine – their contention that the bomber could not be stopped.

Given the B-10's limited range and payload, the possibilities of strategic bombing, however, were still technologically limited. The two-engine B-18 was an improvement on the B-10, but was still ill suited for the mission of strategic bombardment.[173] Only with the advent of the Boeing B-17 "Flying Fortress," Arnold's "air power that you could get your hands on," could the Air Corps realistically hope to execute its bombing doctrine.[174] Designed in 1933 and tested in 1935, the first model of the B-17 had a max speed of 250 miles per hour, a reported service ceiling above 30,000 feet, and a range that exceeded 2000 miles. In a lecture to the Army War College in 1937, an enthusiastic Arnold laid out the advantages of the American version of Douhet's "battleplane:" with its greater carrying capacity, one B-17 could do the work of two B-18s and four B-10's; with a higher cruising speed than the B-18 or the B-10, the B-17 could get to the target in back in significantly less time; with its smaller crew, the B-17 was more efficient than either the B-18 or the B-10; four engines gave the B-17 a greater margin of safety in case of engine failure; and with the B-17's greater range, the Air Corps could more effectively reinforce the defenses of Panama and Hawaii as well as intercept enemy fleets further out to sea. "There is no economy," concluded Arnold,

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[171] Futrell, *Ideas, Concepts, Doctrine*, 1, 63-64. See also Hansell, *The Air Plan that Defeated Hitler*, 18; Faber, "Interwar Army Aviation and the Air Corps Tactical School," 234, note 89; and Tate, *The Army and Its Air Corps*, 159-160.

[172] The B-10 was also the first aircraft to incorporate an enclosed cockpit for its crew. "The Strategic Bomber," 97-98.

[173] Maurer, *Aviation in the U.S. Army*, 360-361.

[174] Arnold, *Global Mission*, 154-156. See also Greer, *The Development of Air Doctrine*, 46-47.

"and there is no worth while argument in favor of the procurement of the less efficient types."[175]

Despite the Air Corps' interest, the Army and the General Staff were less than enthusiastic about procuring the B-17. The acquisition of the B-17 offers an anecdotal illustration of the nonlinear nature of military affairs, where a relatively minor event had major unintended consequences. The Army's reluctance to purchase the B-17 was in part due to the crash of the prototype aircraft at Wright Field in 1935. The crew failed to remove the ground locking pins in the elevator, resulting in the tragic death of two of the five crewmembers and the loss of the unique test aircraft.[176] Because the competitive tests the regulations required could not be completed, the Army allowed the Air Corps only thirteen airplanes for experimental service testing.[177] In place of the other fifty-two B-17's requested by the Air Corps, the Army substituted 133 B-18's, an airplane more suited to close air support.

The thirteen YB-17's were delivered to the Air Corps by August 1936 and served as the core of a strategic bombing force until the B-17 eventually went into full production in 1939. Despite the General Staff's opposition, General Andrews, then commander of the GHQ Air Forces, recommended in 1937 that his units be equipped only with 4-engine bombers (the B-17 was the only operational 4-engine bomber at the time) since they could best fulfill the mission of hemispheric defense.[178] The Army, nonetheless, ordered only twenty-nine B-17's for 1938 and eleven more for 1939. At the

[175] H.H. Arnold, "Address to the Army War College," 8 October 1937, 31-32. AFHRA file no. 248.211-19, part I.
[176] Tate, 165. "The Strategic Bomber," 103. Maurer, *Aviation in the U.S. Army*, 354.
[177] There were obviously other considerations as well. A study produced by the G-4 of the General staff in June 1936 claimed that the big bomber as an offensive weapon inconsistent with national policy that would duplicate functions of the Navy. Medium range bombers like the B-18 were less expensive and sufficient for the task at hand. Craven and Cate, 6, 203. See also Johnson, 163.

time of the German invasion of Poland, the Air Corps had received only fourteen four-engine bombers (the thirteen YB-17's and one XB-15). Even with full production of the B-17, the Air Corps had less than 300 B-17's on hand in December 1941, although more than three years had passed since Roosevelt's call for a 10,000 plane air force.[179]

There were also other Air Corps projects for even bigger bombers beyond the B-17. Project A, initiated in 1934, led to the test flight of the XB-15 in 1937. The XB-15 was twice the size of any aircraft previously flown, but critically underpowered.[180] Project D, initiated in 1935, resulted in the massive, but similarly underpowered, XB-19 in the spring of 1941.[181] The Joint Board countered the Air Corps' programs for an even longer range bomber, declaring in June 1938 that "...it is not considered probable that the Army Air Corps will be called upon in war to perform any missions that require the use of reconnaissance and heavy bombardment planes of greater practical ferrying range, greater tactical radius, and greater carrying capacity than the B-17."[182] Both of these projects, although they ultimately failed to generate production models, made important contributions to the technological know-how that went into the production of later successes like the B-29 and the B-32.[183]

Just as the doctrine for strategic bombing was contingent upon a suitable long-range bomber, the effectiveness of the bomber itself was contingent upon a workable precision bombsight.[184] William Sherman claimed in 1926 that advances in bombsights

[178] Craven and Cate, 6, 204. Tate, *The Army and Its Air Corps*, 166-168.
[179] Craven and Cate, 1, 69-70 and 6, 204. "The Strategic Bomber," 106.
[180] See Craven and Cate, 1, 65-66 and Tate, *The Army and Its Air Corps*, 163-164.
[181] Craven and Cate, 1, 69.
[182] Craven and Cate, 1, 53.
[183] "The Strategic Bomber," 102.
[184] "The [precision bombing] concept originated in 1934 in the Army Air Forces with the development of the gyro-stabilized bombsight and the B-10 airplane. It rests on the assumption that a target that can be seen can be hit if we have a sufficiently accurate sight and the highly skilled personnel to fly the planes, use

had alleviated "the tactical disadvantage under which the bomber formerly labored."[185] But two bombing test fiascos – the Pee Dee River bridge exercise in 1927 and the failure to sink the transport USS *Mount Shasta* – showed that the Army's bombsights were still inadequate to the task of high-altitude precision bombing.[186] Not until 1933 did the Army acquire the "sight of great accuracy" necessary for its emerging doctrine. It is no exaggeration to say that the B-17 was an airplane built around a bombsight – the Norden Mark XV precision bombsight.[187]

American airmen, especially the bombing enthusiasts at the Air Corps Tactical School, had great hopes for the Norden Mark XV because it promised to remove the fundamental sources of bombing inaccuracy – to correct for the irregular and nonlinear in the bombing process.[188] Through a process of synchronization and gyroscopic stabilization during the bombing run, the sight removed the "friction" of air turbulence and aircraft mishandling that complicated fixing the sight on the target. By linking the bombsight to automatic flight controls, the Air Corps further distanced the troublesome human element from the accuracy equation.[189] In 1935, bombing from 15,000 feet with

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the sight properly and drop the bombs ... Precision bombing requires a sight of great accuracy." Notes accompanying draft of *FM 100-20: Command and Employment of Air Power*, 1943. AFHRA file no. 248.211-1.

[185] Sherman, *Air Warfare*, 186.

[186] On the bombing tests, see Murray Green, "The Shasta Disaster: Forgotten Lessons in Interservice Relations," *Air University Review* 30 (March-April 1979), 68-74; and McFarland, *America's Pursuit of Precision Bombing*, 40-43.

[187] For the story of the Norden bombsight, see Stephen L. McFarland, *America's Pursuit of Precision Bombing, 1910-1945* (Washington, D.C.: Smithsonian Institution Press, 1995). For a very detailed technical account from a former Norden bombsight mechanic, see Albert L. Pardini, *The Legendary Norden Bombsight* (Atglen, PA: Schiffer Military History, 1999). On the physics problem involved in accurately delivering aerial bombs given available technology, see especially "The Bombsight," *Flying* 33 (October 1943), 103-107+.

[188] See McFarland, *America's Pursuit of Precision Bombing*, 69.

[189] The Air Corps and Sperry developed an effective automatic flight control system in the 1920's. Unfortunately, the Sperry system could not be efficiently mated with the Norden bombsight. Carl Norden, ever the perfectionist and technological problem-solver, developed his own system of automatic flight controls to meet Air Corps requests. The AFCE ("automatic flight control equipment") linked to the

the new Norden bombsight (designated the M-1 by the Army), the 19th Group at Rockwell Field steadily increased the accuracy of their drops from average errors of 520 feet to 164 feet within a period of forty-one days. As General Arnold later commented, "If airmen go to talking a little too confidently in those days about 'tossing it right in the pickle barrel,' or 'hitting a dime from twenty-five thousand feet,' our continued improvement in bombing with the Norden sight may explain why."[190]

The Norden bombsight was a vast improvement over previous sights, however, interservice competition, the difficulties of integrating and adapting complex technological systems, and the uneven race between technology and doctrine made the process of acquiring the Norden bombsight much less predetermined and "precise" than the mission it was designed to perform. Navy collaboration with Norden on the development of a bombsight was kept secret from the Army until bombing tests against the USS Pittsburgh in October 1931.[191] The Army, forbidden to contact Norden directly, submitted requests through the Navy for seventy-eight of the new sights to replace their assortment of less capable equipment after watching Navy acceptance tests at Dahlgren, Virginia in April 1933.[192] Even after the Army acquired its first sights, the Navy's tight control over the procurement process made it difficult to repair and maintain the sights, delayed production of sufficient quantities to meet Air Corps needs, and spawned confusion between contractors and subcontractors.[193] General Foulois as Chief of the Air

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Norden bombsight first appeared on the B-18 in 1938 and later was standard equipment on the B-17. McFarland, *America's Pursuit of Precision Bombing*, 118-126.

[190] Arnold, *Global Mission*, 150.

[191] McFarland, *America's Pursuit of Precision Bombing*, 44-67 and 72-73.

[192] Craven and Cate, 1, 598. Maurer, *Aviation in the U.S. Army*, 388-390.

[193] "According to Navy production estimates [in December 1941] there would be a cumulative shortage of over 3000 bombsights by June 1943. The lack of that 50-pund assemblage of screws, bolts, gears, springs, and assorted parts threatened to derail the Army Air Forces's strategy for winning World War II." McFarland, *America's Pursuit of Precision Bombing*, 135-139.

Corps, considered the Norden bombsight to be the most important secret under development in the Air Corps. This shroud of secrecy created difficulties between the Army and Navy and complicated relations with Allies who were not allowed access to the sights until well into the Second World War.[194]

The inherent complexity of the Norden bombsight had "recomplicating" effects on mass production with bottlenecks in key, hard-to-manufacture components like precision bearings and optics. Although the calculations behind the processes of the bombsight was exact, the individual components that carried out these processes, given the manufacturing tolerances of the day, were not.[195] Integrating the bombsight into bomber aircraft introduced other problems – radio interference and excessive aircraft vibration drastically reduced the precision capabilities of the sight.[196] Requested Air Corps upgrades to the sight, like glide-bombing attachments, required bureaucratic wrangling with the Navy and Norden and added further technological complexity.

The case of the Norden bombsight clearly illustrates the interdependent relationship between doctrine and technology. The technological potential of a precision bombsight inspired hopes for a doctrine of precision bombing, for better ways of controlling the outcomes of aerial bombing.[197] At the same time, however, technological choices narrowed available options. The bombsight, designed neither for night nor for bombing at high airspeeds at low altitudes, could only be employed effectively during daylight from high altitude. As the Navy increasingly resorted to dive bombing during the war to improve accuracy, many Norden sights sat idle in their depots, despite the

[194] Pardini, *The Legendary Norden Bombsight*, 217. McFarland, *America's Pursuit of Precision Bombing*, 112-134.
[195] McFarland, *America's Pursuit of Precision Bombing*, 74-75.
[196] Pardini, 56 and 126-127.

clamoring of the Army Air Forces for more sights.[198] Designed for visual conditions, the Norden bombsight was essentially useless to the American precision bombing campaign during northern Europe's frequent periods of inclement weather.[199]

The doctrine of precision bombing not only drove which technologies the Air Corps pursued and developed, but also determined which technologies it ignored. Dogmatic adherence to high-altitude precision daylight bombing led American airmen to fervently chase after the heavy bomber and bombsight technology at the expense of developments in fighter aircraft and defensive measures like radar.[200] As one airman remembered, "We never seemed to be able to achieve a balance which would permit effective equipment of all types of aviation for combat purposes."[201] Haywood Hansell, on the other hand, later claimed that ignorance of radar was "fortunate ignorance," since the American doctrine of high-altitude precision daylight bombing might never have come into being had theorists and planners taken radar into account.[202] Seemingly minor diversions of attention – like the disregard for drop tanks and defensive radar – had major consequences on the course of the air war during World War II.[203]

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[197] See for example Allen Raymond, "How Our Bombsight Solves Problems," *Popular Science* 143 (December 1943), 116-119, 212, 214.
[198] McFarland, *America's Pursuit of Precision Bombing*, 62-65 and 98-99.
[199] On American radar bombing and its inherent inaccuracy, see Craven and Cate, 3, 14-20.
[200] Tate, *The Army and Its Air Corps*, 163. See also Muller, "Close Air Support," 173. Claire Chennault, an ardent advocate of pursuit aviation, made his own contribution to the demise of the pursuit airplane by insisting that pursuit aircraft not be developed for the defensive escort role but rather for offensive counterair operations. Johnson, 156-157, and 166; and Hansell, *The Strategic Air War*, 14.
[201] General Earle E. Partridge, USAF Ret., Oral History #610, August 1966, 7. AFHRA file no. K239.0512-610.
[202] Tate, *The Army and Its Air Corps*, 163. See also Louis Brown, *A Radar History of World War II: Technical and Military Imperatives* (Philadelphia: Institute of Physics Publishing, 1999), 19.
[203] Drop tanks had been used by the Air Corps as early as 1929. The Air Force text at the Air Corps Tactical School advocated droppable fuel tanks in 1931. Fabyanic, *A Critique of United States Air War Planning*, 21-22. Radar prototypes had been tested by the Army Signal Corps as early as 1936. Arnold witnessed a successful test of radar interception at Ft. Monroe in November 1938. Brown, *A Radar History of World War II*, 71-73. See also Alan Beyerchen, "From Radio to Radar: Interwar Military Adaptation to Technological Change in Germany, the United Kingdom, and the United States," in Murray and Millett, eds., *Military Innovation in the Interwar Period.*

Acquiring the technology developed for a doctrine of high-altitude precision daylight bombing was primarily the work of two men, General Henry "Hap" Arnold and President Franklin Delano Roosevelt. Throughout his long and distinguished career, Hap Arnold was infatuated with aviation technology.[204] Arnold, although he considered strategic bombing of vital material targets more economical than attacks on civil populations, was one of the few leaders in the Air Corps who had not attended the Air Corps Tactical School and was not a dogmatic disciple of precision bombing.[205] Arnold recognized that effective air power required not only sound conjecture, but also dedicated training and practice and therefore devoted great effort to "furnish[ing] the practical tests for, and proofs of, the Maxwell Field theories" while commander of the 1st Wing GHQ Air Force at March.[206]

Arnold's greatest contribution, however, was in his tireless efforts first as Assistant Chief and later as Chief of the Air Corps in the procurement and volume production of the Boeing B-17 Flying Fortress despite the War Department's unrelenting

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[204] Among the many technological developments associated with Arnold were the Kettering "Bug" (an early guided bomb), radar targeting, jet-assisted takeoffs, glide bombs, and jet engine aircraft. On Arnold's efforts to make the Air Corps a more technologically oriented service, see especially Dik Daso, *Hap Arnold and the Evolution of American Airpower* (Washington, D.C.: Smithsonian Institution Press, 2000). See also Dik Daso, "Origins of Airpower: Hap Arnold's Early Career in Aviation Technology, 1903-1935," *Aerospace Power Journal* (Winter 1996) and "Origins of Airpower: Hap Arnold's Command Years and Aviation Technology, 1936-1945, *Aerospace Power Journal* (Fall 1997). On Arnold and strategic bombing, see John W. Huston, "General H.H. Arnold and Strategic Bombardment," in Horst Boog, ed., *The Conduct of the Air War in the Second World War: An International Comparison* (New York: Berg Publishers Ltd., 1992), 658-682.

[205] See Arnold and Eaker, *Winged Warfare*, 133-134 and H.H. Arnold and Ira C. Eaker, *Army Flyer* (New York: Harper & Brothers, 1942), 263-264. See also Tate, 160-161. On Arnold and strategic bombing, see John W. Huston, "General H.H. Arnold and Strategic Bombardment," in Horst Boog, ed., *The Conduct of the Air War in the Second World War: An International Comparison* (New York: Berg Publishers Ltd., 1992), 658-682. Arnold's enthusiasm for the glide bomb, a less-than-precise means intended to spare bomber crews by keeping them at distance from heavily defended target areas, demonstrated that "General Arnold was not completely sold on manned, daylight, precision bombing doctrine." Daso, "Hap Arnold's Command Years and Aviation Technology."

[206] Arnold, *Global Mission*, 149. Arnold also actively promoted exercises to test other aspects of Air Corps doctrine, especially the effectiveness of interception and escort missions. See H. H. Arnold, "Employment

opposition.[207] Arnold saw the arrival of the first B-17's at Langley in the spring of 1936 as "a turning point in the course of air power."[208] Having learned from the Billy Mitchell affair, Arnold was a far savvier politician than Mitchell; his behind-the-scenes relationship with Harry Hopkins played a large part in President Roosevelt's 1938 call for "Airplanes – now – and lots of them!"[209] Without Arnold's technological vision and political leadership, the Army Air Corps would have entered the test of war without the necessary means to implement its new air doctrine.

Early in his administration, President Roosevelt had substantially reduced Air Corps budgets. His eventual backing for a more robust air force was contingent on several developments. The first was the Air Corps' disastrous performance delivering the airmail in 1934, which airmen cunningly used to their advantage to claim neglect of the air forces.[210] Immediately after taking the Air Corps off airmail duty, Roosevelt petitioned Congress for an additional $10 million to buy more airplanes and improve ground facilities.[211]

A second factor in Roosevelt's air advocacy was his growing recognition of the importance of air power in international relations. With the range of air power increasing, the isolation and security of the United States was no longer a sure thing. Air power was not only increasingly threatening, but could also be used to threaten others.

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of Tactical Units Equipped With Modern Pursuit and Bombardment Airplanes," 26 November 1934. AFHRA file no. 248.211-65C.

207 See especially Arnold, *Global Mission*, 167-169.

208 "From then on the B-17 became the focus of air planning, or rather of the Air Corps' fight to get *an* air plan ... accepted by the Army." Arnold, *Global Mission*, 155-156.

209 Like Mitchell, Arnold was exiled to Fort Riley, Kansas for lobbying congressman for Air Service appropriations and supporting Mitchell's views. Daso, *Hap Arnold*, 113-114. On Arnold's relationship with the Roosevelt Administration, see Arnold, *Global Mission*, 177-194; Underwood, *Wings of Democracy*, 134-135; and Eastman, "The Development of the Big Bombers," 217.

210 See Thomas Spencer, "The Air Mail Controversy of 1934," *Mid-America* 62 (October 1980), 161-172; John F. Shiner, "General Benjamin Foulois and the 1934 Air Mail Disaster," *Aerospace Historian* 25 (Winter 1978), 221-230.

Franklin Roosevelt came to see air attacks as the one threat that might restrain the unwanted behaviors of Adolf Hitler.[212] As William Bullitt explained to Roosevelt during the Munich crisis in September 1938: "If you have enough airplanes you don't have to go to Berchtesgaden."[213] Immediately following the crisis in November, Roosevelt delivered the Air Corps what Arnold called its "Magna Carta," a proposal to build a 10,000 plane air force.[214] Roosevelt, a former navy man, ultimately became an important advocate of strategic air power.[215]

Applying Air Power Doctrine

The experience of air power in war in the 1930's and early 1940's gave strong hints at the wide gulf that stood between the theory of strategic bombing and the reality of its application. The air war in Spain seemed to undermine the most important tenets of precision bombing. One Army Major from the Coastal Artillery wrote, "Bombing has

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[211] Underwood, *Wings of Democracy*, 39-42.

[212] Underwood, *Wings of Democracy*, 77. Hap Arnold explained the Air Corps' understanding of the role of air power in the Munich crisis: "There can be no doubt that this decisive element was the tremendous striking force of bombers possessed by German air power. Those bombardment airplanes were poised for use against vital targets well within the British and French borders. Those bombardment airplanes...probably would have been employed against such targets immediately. England and France...had no effective defense against such air action – they could not match nor counter such Air Power. Hence the fear which forced capitulation and at least a temporary peace." H.H. Arnold, "Address at the Army Command and General Staff School," Ft. Leavenworth, KS, 7 February 1939. AFHRA file no. 248.211-22.

[213] Underwood, *Wings of Democracy*, 129. Arnold was of like mind: "Had England been the possessor of more potent Air Power than Germany, there probably would have been no Munich." H.H. Arnold, "Address to the Army War College," Carlisle, PA, 18 September 1939, 5. AFHRA file no. 248.211-19A.

[214] Eastman, "The Development of Big Bombers," 219, note 46, and Arnold, *Global Mission*, 177-181. The plan was later scaled down to 5,500 airplanes by the middle of 1941, passed by Congress and signed by Roosevelt on 26 April 1939. Known as the Woodring Plan, the expansion proposed raising the strength of the Air Corps to 6,000 planes, 3,203 officers, and 45,000 enlisted men. Underwood, *Wings of Democracy*, 136-137. For a sense of the Arnold's euphoria, see H.H. Arnold, "Before the Graduating Class of 1939, Air Corps Tactical School," 12 May 1939. AFHRA file no. 248.11-4.

[215] On Roosevelt's support for strategic bombing, see also Richard J. Overy, *Why the Allies Won* (New York: W.W. Norton & Co., 1995), 109-110. Haywood Hansell offers an alternative, although not unbiased, view: "...the President [because he had not been directly briefed on AWPD/1 in 1941] never fully grasped the war winning potential of air power." Hansell, *The Strategic Air War*, 41.

not been very accurate on either side in Spain. The bombardiers in the planes have had little difficulty in hitting those targets which cover large areas, but small targets which require precision bombing have seldom been hit."[216] Citing attaché reports from Spain, an Army War College course taught that high-altitude bombing did not work, that the war in Spain had disproved the Flying Fortress concept, and that smaller aircraft that could operate from makeshift fields were of utmost value.[217] Instructors at the Air Corps Tactical School, however, remained relatively indifferent – only one lecture in 1937-38 was offered at the school on the experience of the Spanish Civil War.[218] As Arnold and Eaker wrote in their book *Winged Warfare* in 1941, American airmen thought the wars of the 1930's offered relatively few lessons since they differed significantly from any future war between "first class powers."[219]

The experience of the German Blitz on England and early British bombing operations also demonstrated the difficulties of strategic bombing. American airmen concluded that the Germans "failed to achieve strategic bombing results" because they were an "Air Support Force" not prepared to do precision strategic bombing. German airplanes, unlike the American "Flying Fortress," could not "stand the gaff" of daylight bombing. The last, and perhaps most important explanation for German failure, was that

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[216] Quoted in James S. Corum, "The Spanish Civil War: Lessons Learned and Not Learned by the Great Powers," *The Journal of Military History* 62 (April 1998), 321.
[217] Futrell, *Ideas, Concepts, Doctrine*, 1, 85-86.
[218] See Corum, 318-322; Biddle, *Rhetoric and Reality*, 171-172; and John F. Guilmartin, "Aspects of Air Power in the Spanish Civil War," *Air Power Historian* 9/2 (April 1962), 86.
[219] H. H. Arnold and Ira C. Eaker, *Winged Warfare* (New York: Harper Bros., 1941), 168-171. See also H.H. Arnold, address at the Army War College, Carlisle, PA, 8 October 1937. AFHRA file no. 248.211-19. Arnold concluded that "The powers, capabilities, and limitations of bombardment aircraft have not been demonstrated in the Spanish war." Arnold's address also covered the air experience to date in the war between Japan and China. Arnold also later noted that observer reports from Spain had been both "weak" and "unimaginative." H.H. Arnold, *Global Mission* (New York: Harper & Brothers, 1949), 169. See also Murray, "Strategic Bombing," 126.

the German *Luftwaffe* "did not stick to persistent systematic precision attacks on strategic targets."[220]

Americans were no less critical of British efforts. Even the poor performance of the twenty B-17's in British hands in 1940-41 did not dampen the enthusiasm of American bomber advocates. Americans pointed out that British B-17's were not fully armed, lacked the Norden bombsight, and improperly employed with poor bombing results. Furthermore, the superchargers installed on British B-17B's for flight at higher altitudes were "unflamed dampened," making the bomber unsuitable for night bombardment.[221] The real lesson to be learned from British mishandling of the airplane, insisted American airmen, was that the B-17 could absorb a great deal of punishment.[222] An August 1941 British photoreconnaissance survey, published the following month as part of the Butt Report, showed that only one in five crews were bombing within five miles of their intended targets.[223] Convinced that British inaccuracies were the result of a faulty doctrine of night bombing, Americans interpreted the report as an affirmation of their doctrine of daylight precision bombing.[224]

The unshaken American conviction in daylight bombing was a source of consternation between allies. The decision to stick with precision bombing in the face of

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[220] Notes accompanying draft of FM 100-20: *Command and Employment of Air Power*, 1943. AFHRA file no. 248.211-1. General Carl Spaatz suggested that the German defeat in the Battle of Britain was due to their inadequate bombers which lacked sufficient armor and defensive firepower, poor formation discipline, and a lack of precision bombing aids. Greer, *The Development of Air Doctrine in the Army Air Arm*, 110. See also Wilson, "Origin of a Theory of Air Strategy," 23-24.

[221] Johnson, *Fast Tanks and Heavy Bombers*, 174. On the lack of Norden bombsights in the RAF, see Robert Morgan and Ron Powers, *The Man Who Flew the Memphis Belle* (New York: Penguin Books, 2002), 103-104.

[222] "The R.A.F. was able to teach our own Eighth Air Force a great deal, especially about radar, radio, and navigational aids. However, at the time, the first B-17's were so badly mishandled by R.A.F. Bomber Command's people that it was obvious it was their place to learn; and they didn't." Arnold, *Global Mission*, 261-263. See also Johnson, *Fast Tanks and Heavy Bombers*, 172-173.

[223] Biddle, *Rhetoric and Reality*, 1 and 195. See especially note 82 on page 359 on the contents of the Butt Report.

British experience, on the other hand, was also fortuitous. Combining the two approaches provided a certain synergy in the strategic bombardment of Germany. "There are two ways to win a war," retorted General Ira Eaker to questioning reporters in 1943. "One is to break the enemy's will to fight and the other is to remove his means of waging war. Either way wins a war. Use both and you do it much quicker."[225] With twenty-four hour coverage, the whole of the British and American Combined Bomber Offensive, as much a competition between rival doctrines as it was a combination, was in the end far greater than the sum of its parts.[226]

In July 1941, with American involvement in the European war inevitably approaching, President Roosevelt asked the U.S. military to prepare plans for the future employment of military force. The newly designated Army Air Forces' section of the plan, known as Air War Plans Division/1 (AWPD/1), was the endpoint of the interwar process of doctrinal development, a crystallization of the emerging theory of precision bombing.[227] As Haywood Hansell, one of the four primaries (all former instructors at the Air Corps Tactical School) responsible for the plan later explained, AWPD/1 was the first

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224 Greer, *The Development of Air Doctrine in the Army Air Arm*, 116-117.

225 Gian P. Gentile, *How Effective is Strategic Bombing?: Lessons Learned From World War II to Kosovo* (New York: New York University Press, 2001), 39-40. As General Earle Partridge later noted, "[A]lthough, of course, this was not planned before the war, our daylight bombing complemented that done by the Royal Air Force and the combination was exceedingly effective." General Earle E. Partridge, USAF Ret., Oral History #610, August 1966, 6. AFHRA file no. K239.0512-610.

226 Noble Frankland, "The Combined Bomber Offensive: Classical and Revolutionary, Combined and Divided, Planned and Fortuitous," in William Geffen, ed., *Command and Commanders in Modern Warfare: The Proceedings of the Second Military History Symposium, U.S. Air Force Academy, 23 May 1968* (Washington, D.C.: Office of Air Force History, 1971), 267. See also Craven and Cate, 3, 7.

227 *Air War Plans Division/1*, Washington, D.C., Headquarters of the Army Air Forces, 12 August 1941. AFHRA file no. 145.82-1, parts 1-5. AWPD/1 became Annex 2 of the War Department's "Victory Program." For a comprehensive analyses of AWPD/1 is in Fabyanic, *A Critique of United States Air War Planning*, 49-78. See also Hansell, *The Air Plan That Defeated Hitler*; Hansell, *The Strategic Air War*, 29-41; and DeWitt Copp, "The Pioneer Plan for Air War," *Air Force* (October 1982), 17-25.

real chance for the Air Corps to present its previously heretical doctrine as the official way for American air war.[228]

Planners based AWPD/1 on "the selection of a system of objectives vital to continued German war effort, and to the means of livlihood [sic] of the German people, and tenaciously <u>concentrating all bombing</u> toward destruction of these objectives."[229] Reflecting the Tactical School's emphasis on national economic structures, the intent of AWPD/1 was to "destroy the industrial fabric buttressing the military power and social order in Germany" through "the destruction or paralysis of the vital organs of the state body."[230] Lacking critical intelligence about the German economy and adequate time to gather the necessary information, planners resorted to mirror imaging to determine appropriate targets.[231] The plan, although it sought the disproportional outcomes of destroying certain vital targets, was reductionist in that it failed to address the connections between each of the discrete targets it identified.[232]

The primary objectives of the air campaign against Germany identified by AWPD/1 were the disruption of a major portion of the electric power system of Germany, the disruption of the German transportation system, the destruction of the German oil and petroleum system, and the undermining of German morale by air attack

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[228] Hansell, *The Air Plan that Defeated Hitler*, xi. The four were Hal George, Haywood Hansell, Laurence Kuter, and Ken Walker. See James C. Gaston, *Planning the American Air War: Four Men and Nine Days in 1941* (Washington, D.C.: National Defense University Press, 1982). Haywood Hansell later claimed that the difficult situation was made easier since "We embraced a common concept of air warfare and we spoke a common language." Hansell, *The Strategic Air War*, 31. See also the unpublished memoir of Richard D. Hughes, AFHRA file no. 520.056-234.
[229] AWPD/1, part 5, tab 2, 2. Emphasis in the original.
[230] Hansell, *The Strategic Air War*, 116.
[231] See Hansell, *The Strategic Air War*, 19-22.
[232] Edward J. Felker, *Airpower, Chaos, and Infrastructure: Lords of the Rings*, Air War College Maxwell Paper No. 14 (Maxwell AFB, AL: Air University Press, 1998), 24-25.

of "civil concentrations."[233] A secondary objective – but of "overriding importance" – was the neutralization of the German air force by attacking bases, aircraft factories, and aluminum and magnesium factories. The plan also recognized the "diversion objectives" of attacking submarine bases, surface sea craft, and "invasion" bases that might be imposed by the necessity of securing lines of communication.

Each of these target "systems" was further divided into a total of 154 discrete targets.[234] To calculate the number of aircraft required, planners used the probability tables developed on peacetime bombing ranges and at Maxwell, concluding that it would take 220 bombs for a 90% probability of destroying a 1000 square-foot target. Factoring in the good weather needed for precision bombing, replacement aircraft, and a margin for error for combat conditions, planners "banged and cranked at their Monroe calculators all day long and into the night" to arrive at the requirement for 6,860 heavy bombers.[235] The plan called for an all-out bombing campaign beginning in April 1944 when sufficient numbers of bombers would become available that would continue through September 1944. Estimating the effects of the air effort, AWPD/1 optimistically concluded: "If the air offensive is successful, a land offensive may not be necessary."[236]

The Army Air Forces, armed with visions of the sufficiency of air power, launched their first bombing missions in August 1942. With only a relatively small force of bombers available, however, American planners had to forego "any dreams of causing

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233 Planners noted: "The most effective manner of conducting such a decisive offensive is by destruction of precise objectives, at least initially. As German morale begins to crack, area bombing of civil concentrations may be effective." AWPD/1, tab 2, 2.
234 AWPD/1, part 5, tab 2, 2-13. See also Hansell, *The Strategic Air War*, 34-35 and Stephen A. Parker, "Targeting for Victory: The Rationale Behind Strategic Bombing Objectives in America's First Air War Plan," *Airpower Journal* 3/2 (Summer 1989), 58-70.
235 "Accuracy was degraded by a factor of two and one quarter to take care of bombing accuracy under combat conditions." Hansell, *The Strategic Air War*, 36. See also AWPD/1, part 3, "Basis for Calculations of Force Required to Destroy Targets;" Gaston, 55-58; and McFarland, 102-103.

a Wagnerian cataclysm" and stick to a small number of carefully chosen targets.[237] The relative success of early missions against targets in France within range of British fighter escorts (Americans flew nine missions before suffering their first combat loss) seemed to validate American claims for daylight precision bombing.[238] Gaps between theory and reality, however, were beginning to show.[239]

Air War Plans Division-42 (AWPD-42), an update requested by Roosevelt given the changing strategic situation, reflected the growing divergence between theory and reality and the need for adaptation.[240] Whereas AWPD/1 was a "contingency" plan should the United States enter the war, AWPD-42 was a "requirements" plan based on the actual fact of American involvement in both the European and Pacific theaters.[241] Tempered by the reality of but six American combat missions, AWPD-42 no longer mentioned success by the Air Forces alone. Given the limits of production and the diversion of air resources to both the Pacific and the Mediterranean, planners offered a more subdued assessment of air power's strategic effectiveness, admitting that air power could not set the conditions for invasion of the continent until May 1944. The air plan nevertheless concluded that it was still "perfectly feasible to conduct precise bombing

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[236] AWPD/1, part 5, tab 2, 2.

[237] Economic Objectives Unit, *War Diary*, R&A Branch, OSS London, Vol. 5, 2. AFHRA file no. 520.056-167.

[238] See especially General Eaker's report dated 31 August 1942. AFHRA file no. 142.052 EAKER. General Spaatz wrote to General Arnold: "The operations of the past week ... have convinced me ... that daylight bombing with extreme accuracy can be carried out at high altitudes by our B-17 airplanes. Thomas A. Fabyanic, "Strategic Air Attack in the United States Air Force: A Case Study," Air War College Report No. 5899, April 1976, 62-63. See also Fabyanic, *A Critique of United States Air War Planning*, 203-204; Overy, *Why the Allies Won*, 115-116; and Johnson, *Fast Tanks and Heavy Bombers*, 174-175.

[239] See especially "Report of VIII Bomber Command on Tactical Lessons Learned," 1942. AFHRA file no. 248.211-3.

[240] *AWPD-42, Requirements for Air Ascendancy*, Washington, D.C., The Army Air Forces, 9 September 1942. AFHRA file no. 145.82-42. Roosevelt's request asked for a new plan based on "the proper relationship of air power to the Navy and our ground forces." Roosevelt to Marshall, 24 August 1942. AFHRA file no. 145.82-42. See also Fabyanic, "Strategic Attack in the United States Air Force," 56-73.

operations against selected precision targets, from altitudes of 20,000 to 25,000 feet, in the face of anti-aircraft artillery and fighter defenses."[242]

The mechanistic and deterministic nature of AWPD/1, and to a lesser extent of AWPD-42, violated the paradoxical and nonlinear logic of war.[243] Although the force requirements and eventual outcomes identified in 1941 closely matched the final results, the air war waged in the interim rarely turned out as American expected.[244] As the official Air Force history of the war noted, "The aiming point became a highly theoretical term."[245] Besides closing landing fields and contributing to aircraft collisions, weather frequently obscured targets, frustrating precision bombing. Bombs dropped in salvos from bomber formations were less accurate than probability tables had predicted for individual bombers and bombsights.[246] Technological malfunctions, faulty bombardier technique, and enemy defenses further degraded bombing precision – bombs intended for the "pickle barrel" rarely hit the barn yard in wartime conditions.[247] By the end of the first year, even the most optimistic of airmen could not overlook the difficulties of discriminate bombing of vital targets in the enemy's industrial web.[248]

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[241] Hansell, *The Strategic Air War*, 57-69.
[242] AWPD-42, Tab C. "With our present types of well armed and armored bombers, and through skillful employment of great masses, it is possible to penetrate the known and projected defenses of Europe and the Far East without reaching a loss-rate which would prevent our waging a sustained offensive." AWPD-42, Part IV, 6.
[243] On the mechanistic nature of AWPD/1, see Watts, *The Foundations of U.S. Air Doctrine*, 22-23. On the "major holes" in the doctrine of precision strategic bombing, see McFarland, *America's Pursuit of Precision Bombing*, 98-104.
[244] Hansell, *The Strategic Air War*, 113.
[245] Craven and Cate, 3, 20.
[246] See W. Hays Parks, "Precision and Area Bombing: Who Did Which, and When?" in Mark K. Wells, *Airpower: Theory and Practice* (London: Frank Cass, 1995), 148. See also Maurer, *Aviation in the U.S. Army*, 392-393; and McFarland, *America's Pursuit of Precision Bombing*, 96-97.
[247] See especially Craven and Cate, 2, 269-273. According to the U.S. Strategic Bombing Survey, only 31.8 percent of bombs dropped by the Eighth Air Force in Europe using Norden bombsights from an average of 21,000 feet fell within 1000 feet of their aimpoint. McFarland, *America's Pursuit of Precision Bombing*, 185-186.
[248]According to the U.S. Strategic Bombing Survey, only 31.8 percent of bombs dropped by the Eighth Air Force in Europe using Norden bombsights from an average of 21,000 feet fell within 1000 feet of their

The experience in the air also confirmed the interactive nature of war. Enemy adaptations bolstered defenses against air attack.[249] Rockets and cannons gave the aircraft of the *Luftwaffe* a range advantage against unescorted American bombers. The use of radar and an efficient ground control system made Allied bomber formations, particularly American airplanes flying in the daytime, even more vulnerable.[250] Enemy adaptations not only strengthened defenses, but also changed target sets throughout the course of the war. The Germans decentralized and dispersed their industrial plants, especially those in so-called bottleneck targets, making them more difficult for Allied bombers to find and effectively destroy.[251]

Dogmatic adherence to restrictive assumptions about bombing tactics slowed American adaptation in response. After disastrous missions in August and October 1943 against Schweinfurt and Regensburg located within the well-defended industrial heartland of Germany, airmen began to look more favorably on blind bombing techniques using radar from above protective layers of clouds and the safety of fighter escorts.[252] Airmen in the Army Air Forces (AAF) found they could ill afford to

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aimpoint. See *The United States Strategic Bombing Surveys (European War) (Pacific War)* (Maxwell AFB, AL: Air University Press, 1987), 12-14; and McFarland, *America's Pursuit of Precision Bombing*, 65-90 and 185-186. On the inherent inaccuracy of the American precision bombing campaign against Germany, see especially McFarland, *America's Pursuit of Precision Bombing*, 65-90 and Parks, "Precision and Area Bombing."

[249] See especially Edward B. Westermann, *Flak: German Anti-Aircraft Defenses, 1914-1945* (Lawrence, KS: University of Kansas Press, 2001) and Edward B. Westermann, "Hitting the Mark, but Missing the Target: Luftwaffe Decoy and Deception Operations, 1939-1945," *War in History* (Spring 2003), 206-221. See also Richard R. Muller, "Losing Air Superiority: A Case Study from the Second World War," *Air and Space Power Journal* (Winter 2003); and Overy, *Why the Allies Won*, 117-119.

[250] Johnson, *Fast Tanks and Heavy Bombers*, 209-210.

[251] Craven and Cate, 3, 40; and Hansell, *The Air Plan That Defeated Hitler*, 180-184 and 207-208. On the changing nature of German industrial targets throughout the war, see also McFarland, *America's Pursuit of Precision Bombing*, 103.

[252] "When precision bombing is impossible in either Germany or in the tactical area, the blind bombing of large cities containing important military targets is the best use of the bomber force. Such attack in great weight, offers a reasonable chance of direct damage to important war production, and of some useful indirect effects." EOU *War Diary*, 124. See also Overy, *Why the Allies Won*, 121-124; Parks, "Precision and Area Bombing," 153-154; Biddle, *Rhetoric and Reality*, 224-227; and Craven and Cate, 2, 681-683.

concentrate solely on the strategic level of war at the expense of the tactical and operational levels, that the levels of war were interdependent and inseparable. Strategic bombardment and aerial superiority were inextricably interlinked.[253] Following the losses of October, Americans halted raids deep into Germany until a sufficient quantity of better quality fighter escorts became available in February 1944.[254] Air war in the event was less the engineering project than planners trained at the Air Corps Tactical School had imagined.[255]

American strategic bombing against Germany, while still cloaked in the vocabulary of precision, came to resemble British area bombing in application, if not in intent.[256] In the last quarter of 1944, approximately seventy-five percent of American bombing missions in Europe used some kind of blind bombing techniques.[257] In the Pacific theater, facing potentially catastrophic losses should the failure of strategic bombing necessitate the invasion of Japan, airmen turned to firebombing Japanese cities and the atomic bomb.[258] As pragmatic commanders like Curtis LeMay contended,

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[253] See especially *The United States Strategic Bombing Surveys*, 16; Fabyanic, *A Critique of United States War Planning*, 185.and Futrell, *Ideas, Concepts, Doctrine*, 1, 154-155.

[254] Although Hansell complained that "The diversion of the strategic air effort was a tragic mistake," this change was an acknowledgement of the inadequacies of the doctrine of unescorted bombing and the necessity of air supremacy for a successful campaign against Germany's industrial heartland. Hansell, *The Strategic Air War*, 85-90 and 129.

[255] Watts, *The Foundations of U.S. Air Doctrine*, 59-85.

[256] See especially Crane, "Evolution of U.S. Strategic Bombing of Urban Areas," and Parks, "Precision and Area Bombing." See also Thomas, *The Ethics of Destruction*, 133-134. Crane counters that "The contention that American nonvisual bombing was the equivalent of area bombing is not supported by the record of European air operations. ...the key difference between the two air forces lay in their targets. ...There was a large difference between the RAF and the AAF both in intent and effort as to the number of civilians killed." Crane, *Bombs, Cities, and Civilians*, 74-76.

[257] Conrad C. Crane, "Evolution of U.S. Strategic Bombing of Urban Areas," *The Historian* 50/1 (1987), 26.

[258] Fabyanic, "Strategic Air Attack in the United States Air Force," 171-175. Unlike the European theater, area attacks made up seventy percent of the Army Air Force's bombing campaign in the Pacific theater. Gian P. Gentile, *How Effective is Strategic Bombing? Lessons Learned from World War II to Kosovo* (New York: New York University Press, 2004), 121.

imprecision taught target populations "a solid lesson in the disadvantages of war."[259] "The logic of total war," notes historian Richard Overy, "became self-fulfilling."[260]

The Nonlinear Reality of Air Warfare

Determining the origins of American precision air power is a daunting task. This is due to the contingent and interactive nature of the processes involved in the formation of air power doctrine during the interwar period.[261] The experience of war, interservice rivalry, the thoughts and actions of influential individuals, technological developments, and their social and political contexts all played a necessary role in the emergence of an American doctrine for precision air power. Although necessary, none of these influences alone was sufficient. All were interdependently related in complex and unquantifiable ways.

While the Army may very well have been preparing for the last war (as airmen accused), the Air Corps prepared for the war it preferred to fight. The Air Corps, as a more technologically oriented branch with less experience in practical application, adopted somewhat mechanistic and overly engineered theoretical solutions to the problems of air power. The sources of this scientism included not only the general American penchant for technological solutions, but also the advocacy of key agents like Douhet, Mitchell, and the instructors at ACTS, as well as the ethical and political appeal of more humane warfare and economic demands for greater military efficiency.

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[259] McFarland, *America's Pursuit of Precision Bombing*, 189.
[260] Overy, "Introduction," in Cox and Gray, xv.
[261] "A complete account," writes Thomas Greer, "of the gestation, birth, and growth of the precision concept and tactics is impossible." Greer, *The Development of Air Doctrine*, 57. Michael Sherry expresses a similar sentiment: "[T]he rise of American air power rested on arguments whose collective force was greater than the sum of their parts." Sherry, *The Rise of American Air.Power*,xii and 49-53.

High altitude daylight precision bombing, the evolutionary ancestor of modern precision air power, promised to maximize the efficiency of air warfare by offering potentially large effects for a minimum of bombing inputs. The technological, political, and economic uncertainty of the interwar period, however, left theoretical holes that American airmen had to paper over with unproven assumptions about the survivability of the bomber, the accuracy of bombing in the face of defenses, and the lack of resilience of industrialized opponents. As Morris Janowitz writes, planning for war is fraught with uncertainties and dogmatic doctrine is a typical organizational response to these uncertainties.[262] The Air Corps' dogmatic belief in the correctness of their theoretical schema and its assumptions caused most airmen to overlook other potential alternatives for the use of air power. Even when the empirical trials of the Spanish Civil War and the British experience in the early days of World War II pointed to potential shortcomings in strategic bombing, airmen stuck by their assumptions, widening the gap between theory and the nonlinear reality of war.

The errors in these interrelated assumptions compounded into even greater miscalculations about the outcomes of air warfare.[263] As Thomas Fabyanic has noted, "All of the assumptions contained inherent weaknesses, which, for the most part, were not serious if taken independently. But collectively, the shortcomings were mutually exclusive and thus made the entire concept a tenuous one."[264] The ultimate political and

[262] Morris Janowitz, *The Professional Soldier: A Social and Political Portrait* (New York: The Free Press, 1971), 24.
[263] Biddle, *Rhetoric and Reality*, 91.
[264] Fabyanic calls this "the accumulation of risks". Fabyanic, "Strategic Air Attack in the United States Air Force," 163-164. Michael Sherry borrows from Fabyanic: "Strategic bombing theory was like the complex modern society airmen imagined, so interdependent in it assumptions that the failure of one component would unravel the whole thing." Sherry, *The Rise of American Air Power*, 55-57. See also Fabyanic, *A Critique of United States Air War Planning*, 47 and 206-207; and Sherry and Murray, "Strategic Bombing," in Murray and Millett, eds., *Military Innovation in the Interwar Period*, 127.

strategic effects of high-altitude precision daylight bombing, despite best intentions, proved less amenable to accurate prediction and control than air power enthusiasts at ACTS had hoped.

Air power, although it did not succeed in the ways originally intended, did indeed make decisive contributions to Allied victory. Advocacy of strategic bombardment provided the necessary means – the airplanes, airmen, and logistical infrastructure – for the successful application of air power in World War II. Airmen, however, had to adapt their ways of using these means to the contextual realities of the war. It was not just the Army Air Forces' destruction of Germany's industrial web, but also the defeat of the German Air Force, that proved essential, both in the air and on the ground, to Allied victory. Another way that airmen adapted air power to the task at hand was in using bombers to interdict German lines of communication prior to the invasion of Normandy in 1944. Diverted from its "independent" strategic mission to the mission of aerial interdiction in support of the invasion, air power played an important role in enabling Allied ground forces in Western Europe. The following chapter describes this successful adaptation.

Adapting Precision Air Power: The Transportation Plan

"But in war, as in life generally, all parts of a whole are interconnected and thus the effects produced, however small their cause, must influence all subsequent military operations and modify their final outcome to some degree, however slight."

Carl von Clausewitz[1]

American airmen entered World War II with plans for using air power against vital strategic targets deep in the heart of Germany. Military and political necessities, however – those factors that distinguish real war from war on paper – frequently diverted air power from its doctrinally preferred uses. In the spring of 1944, the most pressing necessity was success of the upcoming invasion. Military commanders, therefore, redirected American bombers from their independent air campaign against German industry to attacks against lines of communication in Belgium and northern France. High flying B-17 and B-24 heavy bombers, however, lacked the necessary technological capabilities and operational methods and therefore proved less precise in attacking railways, roads, and bridges – the German lifelines to the landing beaches – than tactical aircraft attacking from lower altitudes. Shaped by the demands of war, American precision air power, once envisioned exclusively as heavy bombers attacking strategic nodes of an enemy's industrial web, transformed to include attacks by fighters and medium bombers in direct support of the land campaign.

How best to adapt the means and methods of air power to support Operation OVERLORD was the source of vigorous debate prior to the invasion.[2] Even after the

[1] Carl von Clausewitz, *On War* (Princeton, NJ: Princeton University Press, 1976), 158.
[2] The issue of control of the strategic bombers prior to OVERLORD was the only issue throughout the war over which Eisenhower threatened to resign. See also Forrest C. Pogue, *The Supreme Command* (*The United States Army in World War II: The European Theater of Operations*, v. 3, part 4) (Washington, D.C.: Government Printing Office, 1954), 123-127.

successful invasion, the debate was no less acrimonious as airmen and analysts sought to explain how and why air power had succeeded. More than sixty years after the event, there is still no clear agreement on whether attacks on rail yards, on bridges, or on oil facilities in the interior of the German Reich were the leading factor in the *Wehrmacht*'s failure to throw back the Allied invasion. Perhaps the clearest lesson from the case of Allied air power in the spring of 1944, then, is the difficulty of precisely parsing the relationship between applied causes and desired effects in air warfare.

The Changing Operational Environment

By the end of 1943, American precision air power was clearly failing to achieve intended strategic results. Leaders in the Army Air Forces, under increasing political pressure to live up to their pre-war promises, looked for new ways to employ air power.[3] General Hap Arnold, then Chief of the Army Air Forces, saw the solution in tactical and technological innovation: "To hasten the end of the war we must achieve the maximum flexibility in our bombing operations, by altering our technique, employing new gadgets, and by any other means found practicable… to secure an uninterrupted bombing offensive of the greatest possible effectiveness."[4] By adapting the tactical and

[3] Michael Sherry, *The Rise of American Air Power: The Creation of Armageddon*, (New Haven, CT: Yale University Press, 1987), 160-161. Wesley Frank Craven and James Lea Cate, eds., *The Army Air Forces in World War II*, 7 vols., new imprint of 1948-1958 editions (Washington, D.C.: Office of Air Force History, 1983) 2, 719.
[4] Arnold quoted in Tami Davis Biddle, *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas About Strategic Bombing, 1914-1945* (Princeton, NJ: Princeton University Press, 2002), 232.

operational application of air power, airmen like Arnold hoped to achieve greater control over desired strategic outcomes.[5]

One of the most significant technological adaptations in the bomber war was the development of radar bombing equipment and techniques.[6] Heavy cloud cover over Europe in the fall and winter frequently precluded visual bombing, forcing airmen to rely on "blind bombing" using H2S/X radar equipment to find obscured targets.[7] Although "weather continued to be a faithful Nazi collaborator," radar bombing made possible missions of increasing size and frequency.[8] Radar bombing also offered some measure of protection as cloud layers, at least early in the war, made it more difficult for German aerial and ground defenses to locate Allied bomber formations. From October 1943 through February 1944, the Allied Combined Bomber Offensive became, as the official Air Force history attests, "essentially the story of an experiment in radar bombing."[9]

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[5] The best first-hand account of the tactical adaptations of American strategic bombing to the challenges of the war is in Haywood Hansell, *The Air Plan That Defeated Hitler* (Atlanta: Higgins-McArthur/Longino & Porter, Inc., 1972), 113-143.

[6] The British were the first to employ radar target finding in the European air war. American radar equipment, the H2X, was an improved version of the British system, the H2S. Originally designed only for navigation, the H2S was first employed operationally in September 1943 and the H2X in November 1943. Radar bombing should more correctly be called radar-assisted bombing as the H2X system was used in conjunction with the Norden bombsight, replacing the function of its optical bombsight when clouds visually obscured the target. See Stephen L. McFarland, *America's Pursuit of Precision Bombing, 1910-1945* (Washington, D.C.: Smithsonian Institution Press, 1995), 179-183; Craven and Cate, 2, 720-721; and Conrad C. Crane, *Bombs, Cities and Civilians: American Airpower Strategy in World War II* (Lawrence, KS: University Press of Kansas, 1993), 66-77. For a contemporary analysis of the various types of radar bombing equipment, see Sol E. Ernst, "Radar Bombing (H2X)", lecture at the AAF School of Applied Tactics, May 1945. AFHRA file no. 248.21-10.

[7] In the 180-day period from October 1943 to March 1944, there were only 38 days suitable for visual bombardment. United States Strategic Bombing Report No. 62, *Weather Factors in Combat Bombardment Operations in the European Theater* (Washington, D.C.: U.S. Government Printing Office, 1947), 29. See also McFarland, *America's Pursuit of Precision Bombing*, 178. General Arnold, committed to precision bombing, forbid the use of the phrase "blind bombing" in describing radar bombing procedures. Richard G. Davis, *Carl A. Spaatz and the Air War in Europe* (Washington, D.C.: Center for Air Force History, 1993), 297.

[8] Craven and Cate, 3, 21.

[9] Craven and Cate, 3, 13-14. See also Richard Davis, "German Rail yards and Cities: U.S. Bombing Policy 1944-1945," *Air Power History* 42 (Summer 1995), 46-63. Davis mistakenly claims that the Army Air Force had abandoned its faith in prewar precision doctrine. It is probably more true to say that they had not abandoned the faith, but continued to seek ways of making precision air power possible. Although many of

Airmen hoped that radar targeting would improve accuracy, but this hope proved unfounded as the limits of radar technology caused even greater bombing inaccuracy and imprecision.[10] As the U.S. Strategic Bombing Survey concluded after the war, "It cannot be said that this equipment was in any sense a precision bombing instrument."[11] In November and December 1943, bombs fell in the assigned target area on only two radar missions.[12] Of the 279.5 tons of bombs dropped on the I.G. Farben plant using H2X during the winter of 1943 and 1944, only thirty-six tons actually found their target.[13] Radar targeting equipment also had the negative unintended consequences of atrophying crewmembers' visual bombing skills and, after German technicians found they could use Allied radar emissions to pinpoint the location of bombers using H2S/X, making it easier for the *Luftwaffe* to intercept bomber formations.[14] Radar bombing, intended to give greater precision to bombing through cloud cover, had a negligible effect on the outcomes of the strategic bombing campaign.

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these ways turned out to be markedly imprecise, the theoretical goal of accurate, precision bombing remained nonetheless. See Davis, *Carl A. Spaatz*, 298.

[10] These hopes for greater accuracy "contributed to an unfortunate tendency to treat H2X as a rival of visual bombing rather than a supplement to it." Craven and Cate, 3, 17. Other factors also contributed to the inaccuracy of visual bombing supplemented by radar. As one radar navigator-bombardier related, "Our accuracy was affected not only by the limited resolution of our radar, but also by haze; solid or broken undercast; smoke, either from German smoke generators or preceding bombing; turbulence; the variable skills of crews; equipment malfunction; flak; inaccurate calculations; unknown winds aloft; the tension of doing an exacting and precise job while being shot at; loose formation; and the myriad unforeseen complications affecting a large number of men operating complicated machinery under extreme conditions." Milt Groban letter, *Commentary* (July 1978), 10-11.

[11] U.S. Strategic Bombing Survey, Military Analysis Division, *Bombing Accuracy: USAF Heavy and Medium Bombers in the ETO*, vol. 63 (Washington, D.C.: Government Printing Office, 1947), 4.

[12] Craven and Cate, 3, 20-22. For the 8th AF throughout the entire war, only .2% of bombs fell within 1000 feet of the target when using H2X alone, while 41% of bombs fell outside of a five-mile radius. McFarland, *America's Pursuit of Precision Bombing*, 183. Jimmy Doolittle claimed that radar bombing was "analogous to shooting into a flock of ducks rather than selecting your duck." Quoted in Biddle, *Rhetoric and Reality*, 229.

[13] Craven and Cate, 3, 22. The Farben plant was Germany's largest producer of synthetic rubber and diethyl benzene for aviation gas. McFarland, *America's Pursuit of Precision Bombing*, 175.

[14] Crane, *Bombs, Cities and Civilians*, 70; Sir Arthur Harris, *Bomber Offensive* (New York: Macmillan, 1947), 201; and Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany, 1939-1945* (London, 1961), 3, 308.

Radar bombing did, however, change American bombing strategies. Planners frequently selected targets not for their strategic significance, but for their distinct radar signatures.[15] The limited availability of H2X equipment and trained aircrews also imposed new operational requirements. Large formations of bombers dropped bombs in salvos at the signal of single "pathfinder" aircraft armed with radar, a technique less accurate than bombing by individual aircraft or by smaller formation elements.[16] Scarcity of radar equipment and crews also limited the scope and frequency of blind bombing missions. The 15th Air Force in the Mediterranean, for example, did not begin a radar bombing campaign until the spring of 1944 because it lacked the necessary crews and equipment.[17] The tactical adaptation of radar bombing, although it did little to improve bombing accuracy, nevertheless had an important impact on American bombing tactics and strategy.

Measuring the effects of radar bombing was exceedingly difficult since the same cloud cover and protective smoke screens that necessitated radar bombing also limited accurate bomb damage assessment. Lacking a means for accurate assessment, analysts instead related the effects of blind bombing quantitatively to American bombing effort. In fact, however, *effort* and *effect* were not necessarily related.[18] Although Americans

[15] The increasing frequency of attacks on Wilhemshaven in the winter of 1943-1944 demonstrates how radar drove the strategic selection of targets. Despite its limited strategic value, especially after the turn of the tide in the Battle of the Atlantic, the port and surrounding coast line were easily identified on radar. Its proximity to England also allowed for increased protective fighter cover and minimized the time for bombers over enemy defenses enroute. Craven and Cate, 3, 14-17.

[16] The 8th Air Force had only twelve H2X- and four H2S-equipped aircraft during this period. Davis, "German Rail yards and Cities," 51. The "drop on the leader technique" had become standard practice even before the introduction of radar bombing as a way of maintaining the defensive integrity of bombing formations. The limited availability of H2X equipment only reinforced the use of these tactics. See "Formation and Bombing Procedures," in Martin W. Bowman, *USAAF Handbook, 1939-1945* (Mechanisburg, PA: Stackpole Books, 1997), 103-112; McFarland, *America's Pursuit of Precision Bombing*, 170-172; and Hansell, *The Air Plan That Defeated Hitler*, 118 and 252.

[17] Craven and Cate, 3, 25-26.

[18] Sherry, *The Rise of American Air Power*, 162.

were launching more airplanes and dropping more bombs thanks to radar, the effects of bombing, due in part to the dispersion and "recuperability" of German industrial targets, were not proportionally greater. There were indeed certain positive higher order effects of bombing such as the loss of efficiency with the dispersal of German industry and the cost of air defense which, although exceedingly difficult to quantify, undoubtedly impacted the German war effort. The increase in German fighter production and the continuing loss of bombers despite American attacks against aircraft production facilities, however, were irrefutable signs of the limited effectiveness of radar "precision" bombing.[19]

Changing air strategy was a function of the difficulties of precisely destroying intended targets, the scarcity of air power resources, the strength of German opposition, and the problems of accurately measuring the effects of bombing. More importantly, changing strategy in the spring of 1944 reflected the larger military and political focus on the upcoming ground invasion.[20] With General Dwight Eisenhower's arrival in London in January 1944 as Supreme Commander, Allied Expeditionary Forces, Operation OVERLORD became the centerpiece of Allied effort on the ground as well as in the air.

The success of Operation OVERLORD (and any renewed strategic air offensive) was contingent on air superiority. Reacting to losses at the end of 1943, General Arnold's New Year order commanded the Army Air Forces to "*Destroy the Enemy Air Force wherever you find them, in the air, on the ground, and in the factories.*"[21] The new Combined Chiefs of Staff (CCS) directive for the air war of 13 February 1944

[19] Craven and Cate, 2, 729-730.
[20] Hansell, *The Air Plan That Defeated Hitler*, 146-148.
[21] Robert F. Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1907-1960,* vol. 1 (Maxwell AFB, AL: Air University Press, 1989), 153. Craven and Cate, 3, 8.

designated the destruction of the *Luftwaffe* as an *immediate* objective, not an *intermediate* objective as in AWPD/1 and the Combined Bomber Offensive.[22] The height of the counter air campaign occurred in February with Operation ARGUMENT, known to airmen as "Big Week," that took advantage of a fortuitous week of clear weather to renew attacks against the German aircraft assembly industry.[23] ARGUMENT involved renewed strikes against targets first hit in the fall of 1943. The overall effects of this much larger effort, however, on production were less significant than in earlier attacks due to the dispersal of German production facilities. The effects on the German aircraft assembly, however limited, came at a serious cost to the Allied air effort – 266 heavy bombers and 2600 aircrew members.[24]

The success of American air strategy was also contingent on other operational developments. Thanks to more capable fighter escorts, like the P-51 Mustang equipped with drop tanks to extend its range, what had been impossible in 1943 was now possible in the spring of 1944.[25] The availability of effective long-range escort fighters was, in fact, the single most important development in the transformation of the air war over Europe.[26] At General Arnold's insistence, less capable P-38's and P-47's were sent to the tactical forces of the 9th Air Force, while the new longer-range P-51's were reprioritized

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[22] Hansell, *The Air Plan That Defeated Hitler*, 177-180. See also Bowman, *USAAF Handbook*, 49.
[23] During Big Week, 3300 bombers from the 8th AF and more than 500 from the 15th AF dropped nearly 10,000 tons of bombs on the aircraft industry (more tonnage than the 8th had delivered in the entire previous year). Although the Big Week attacks destroyed 75% of the structures that sustained 90 percent of German aircraft output, German adaptations and spare capacity allowed them to continue to increase aircraft production. *With Courage*, 224-226. See also General H.H. Arnold, "Second Report of the Commanding General of the Army Air Forces to the Secretary of War," 27 February 1945, in *The War Reports* (Philadelphia: J.B. Lippincott Co., 1947), 361-362; and Sherry, *The Rise of American Air Power*, 162-163.
[24] Biddle, 232.
[25] Richard J. Overy, *Why the Allies Won* (New York: W.W. Norton & Co., 1995), 123.
[26] Craven and Cate, 2, 705-706.

to the strategic bombing missions of the 8th Air Force.[27] By March 1944, P-51s were accompanying 8th AF bombers to Berlin and back.

Success in the air was not only the result of increasing Allied strength, but also of increasing German vulnerability. The most important effect of "Big Week" in February was not the damage done to German industry, but the number of experienced pilots the *Luftwaffe* lost in opposing the bomber assault.[28] German pilots thrown into the air war with inadequate training time flew at a qualitative disadvantage to American and British pilots.[29] German strategy changed from one of confrontation to conservation. American bombing routes first designed to avoid fighter concentrations now deliberately sought to provoke German attack. At the insistence of the new commander of the 8th Air Force, General Doolittle, fighter escorts were freed from the duties of close escort to actively seek out and destroy German fighters in the air and on the ground.[30] The disastrous effects of the new Allied strategy on the *Luftwaffe* were fully apparent by March 1944, a true turning point in the air war, as loss rates for bombers began to sharply decrease.[31]

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[27] Craven and Cate, 3, 11-12. See also Davis, *Carl A. Spaatz*, 316.

[28] Williamson Murray, *Luftwaffe* (Baltimore, MD: Nautical and Aviation Publishing Co. of America, 1985), 226-232; Geoffrey Perrett, *Winged Victory: The Army Air Forces in World War II* (New York: Random House, 1993), 288-289 and 295; and W.W. Rostow, *Pre-Invasion Bombing Strategy: General Eisenhower's Decision of March 25, 1944* (Austin: University of Texas Press, 1981), 24-30.

[29] Craven and Cate, 3, 62. Lionel Lacey-Johnson clearly describes the nonlinear nature of the problem facing the Luftwaffe: "Each part of the problem was interrelated, which created a knock-on effect. A vicious circle began wherein increased losses led to heavier demands for pilots, which in turn led to less pilot training, and ended inevitably with even heavier losses through combat and accidents. When some sort of order was finally restored, there was such a severe shortage of fuel that advancing Allied ground forces found new, serviceable aircraft which had never taken part in the fighting." Lionel Lacey-Johnson, *Point Blank and Beyond* (Shrewsbury, England: AirLife Publishing Ltd, 1991), 29.

[30] Charles P. Cabell, *A Man of Intelligence: Memoirs of War, Peace, and the CIA* (Colorado Springs, CO: Impavide Publications, 1997), 116-117. See also Geoffrey Perrett, *Winged Victory: The Army Air Forces in World War II* (New York: Random House, 1993), 284-285; and Stephen L McFarland and Wesley Phillips Newton, "The American Strategic Air Offensive Against Germany in World War II," in R. Cargill Hall, ed., *Case Studies in Strategic Bombardment* (Washington, D.C.: Office of Air Force History, 1998), 211-213.

[31] See especially John F. Ramsey, *The War Against the Luftwaffe: AAF Counter-Air Operations, April 1943-June 1944*, USAF Historical Study No. 110 (1945). AFHRA microfilm reel no. K1013. See also Craven and Cate, 3, 56-57; and Cabell, *A Man of Intelligence*, 117.

Besides adapting air tactics and strategies, the Army Air Forces also adapted their organizations. To instill new life into the American air campaign, General Arnold reshuffled his top commanders in January 1944.[32] Ira Eaker went to the Mediterranean to lead the 15th Air Force while James Doolittle took Eaker's place in command of the 8th Air Force in England. Carl "Tooey" Spaatz took command of the newly created US Strategic Air Forces in Europe (USSTAF) to better coordinate the efforts of the 8th AF and the 15th AF against targets in the heart of Europe.[33] Arnold pushed for the creation of the USSTAF to elevate the status of the American strategic air campaign above the potentially undermining influences of both the Army and the tactical Allied Expeditionary Air Forces (AEAF) under Air Chief Marshall Sir Trafford Leigh-Mallory, who airmen feared might try to wrest control of the heavy bombers as D-Day approached.[34]

The two American units primarily involved in the pre-invasion air campaign in the spring of 1944 were the tactical forces of Lewis Brereton's 9th Air Force (assigned to Leigh-Mallory's AEAF) and the strategic bombers in Jimmy Doolittle's 8th Air Force (under Spaatz in the USSTAF). Having just moved to England from the Mediterranean in October 1943, the combat elements of the 9th Air Force included: the IX Bomber Command equipped with Douglas A-20 and Martin B-26 medium bombers; the IX

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[32] Sherry, *The Rise of American Air Power*, 161-162. McFarland and Newton, "The American Strategic Air Offensive," 208.

[33] Alfred M. Beck, ed., *With Courage: The U.S. Army Air Forces in World War II* (Washington, D.C.: Air Force History and Museums Program, 1994), 209; Cabell, *A Man of Intelligence*, 111; and Dwight D. Eisenhower, *Crusade in Europe* (New York: Da Capo Press, 1977), 220. In addition to *operational* control of the 8th and 15th AF, Spaatz as the senior AAF commander in England also had *administrative* control over the 9th AF.

[34] See Davis, *Carl A. Spaatz*, 415-416; and Craven and Cate, 2, 741-742. "[Leigh-Mallory] had no experience of broad strategic air warfare, and he had never had the benefit of service at high levels of the Air Ministry or on matters involving the various Committees serving the British Chiefs of Staff Committee." Hansell, *The Air Plan That Defeated Hitler*, 174. See also Max Hastings, *Overlord: D-Day*

Fighter Command with a mix of P-38, P-47, and P-51 fighters; and the transport aircraft of the IX Troop Carrier Command.[35] Originally designated VIII Bomber Command, the 8th Air Force consisted mainly of four-engine Boeing B-17 Flying Fortresses, but also included fighter escorts of the VIII Fighter Command.[36] When Doolittle took command of the 8th AF in January 1944, he had twice the number of B-17's and B-24's that Eaker had in October 1943 thanks to increased production and accelerated training programs in the United States.[37]

By the spring of 1944, the Army Air Force had sufficient bombers and crews to conduct both an interdiction campaign as well as to strike opportunistically at strategic targets when clear weather exposed them to high-altitude precision daylight bombing. From midyear 1943 to the end of December, the total number of heavy aircraft available in the European theater increased from 1,260 to 4,242.[38] By March of 1944, the buildup of the necessary supporting infrastructure of airfields, supply depots, and personnel facilities in England was an accomplished fact. The greater availability in 1944 of aircraft, aircrews, and supporting infrastructure gave more alternatives in the adaptation of American air power.

As the Combined Bomber Offensive reached its designated end date on 1 April 1944, both the American air power system and its operational context had changed immeasurably from 1943. Tactics and strategies had evolved, organizations had changed,

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and the Battle for Normandy (New York: Simon & Schuster, Inc., 1984), 44-45; and Craven and Cate, 3, 4-5.

[35] See Bowman, *USAAF Handbook*, 67-68. For a history of the development of the 9th AF, see Craven and Cate, 3, 107-137. On the 9th's role within the Allied command structure, see Davis, *Carl A. Spaatz*, 307.

[36] On the buildup of the 8th AF, see Murray, *Luftwaffe*, 223-224.

[37] Beck, ed., *With Courage*, 223.

[38] Edward T. Russell, *Leaping the Atlantic Wall: Army Air Forces Campaigns in Western Europe, 1942-1945* (Washington, D.C.: Air Force History and Museums Program, 1999), 7; and Craven and Cate, 2,

and new and more plentiful means were now available to meet a coevolving German enemy. On the verge of failure in 1943, American air power in the spring of 1944 stood ready to take advantage of the possibilities the new operational environment offered.

The Transportation Plan (on paper)

American airmen, in their preparations for Operation OVERLORD, thus faced an entirely new air war. After 14 April until 1 June 1944, operational control of the heavy bombers of the 8th Air Force rested in the hands of SHAEF and the Supreme Commander, General Eisenhower.[39] As early as May 1943, the rewritten Casablanca Directive described the goal of the Combined Bomber Offensive as the weakening of German military power "to permit the initiation of final combined operations on the continent."[40] All agreed that air superiority over the beaches was necessary for success of the invasion – both the Transportation Plan and its rival, General Spaatz' Oil Plan, listed the defeat of the *Luftwaffe* as a primary objective. Disagreement over how this should be accomplished and which secondary objectives would best support the invasion, however, fueled one of the liveliest and most controversial debates of the war.[41]

716-719. Between October 1943 and February 1944, the number of heavy bomber groups increased from 26 to 48. Futrell, *Ideas, Concepts, Doctrine*, 1, 153.

[39] Operational control of the 8th AF went to HQ AEAF under Leigh-Mallory on 1 June for direct support of the invasion. *Sunday Punch*, 8. Leigh-Mallory retained control of the strategic bombers for a few days after the invasion when operational authority returned to Eisenhower and Tedder at SHAEF. Operational control returned to the Combined Chiefs of Staff in the fall, but with greater say going to General Arnold to prevent any attempts by Portal and Harris to subjugate American forces to British area attacks. See David R. Mets, *Master of Airpower: General Carl A. Spaatz* (Novato, CA: Presido Press, 1988), 258-259.

[40] Hansell, *The Air Plan That Defeated Hitler*, 168-171.

[41] Rostow, *Pre-Invasion Bombing Strategy*, 3-4 and David MacIsaac, *Strategic Bombing in World War Two: The Story of the United States Strategic Bombing Survey* (New York: Garland Publishing, Inc., 1976), 18-20 and 75-77. Eisenhower contended the difficulty of arriving at a satisfactory air plan was "because of the widely scattered interests of the air forces and the great strength of units that have been acting in almost an independent way." Robert H. Ferrell, ed., *The Eisenhower Diaries* (New York: W. W. Norton and Co., 1981), 117. Solly Zuckerman (see below) was even more critical: "The strategic air forces were almost sovereign powers engaged in some conflict of their own.... They ruled over their commands like feudal

The most direct option for an operational air power schema in support of the invasion was the straightforward attrition of the military manifestations of German power, i.e. targeting and destroying German tanks and airplanes in northwestern Europe that might oppose the invasion. Given the prejudices of existing air doctrine and the scale of effort this required, airmen quickly ruled out this option. A less direct option was an interdiction campaign to prevent movement toward the beaches by disrupting the roads and railways or lines of communication that led to and from the front. The most indirect option was to strike at the sources of German power – oil and synthetic fuel facilities – which might have the secondary effects both of immobilizing any military opposition to the invasion and disabling the German economy as a whole. The debate over pre-invasion air planning, therefore, hinged on striking either transportation or oil, and which of these two target systems, after taking into account any indirect or "cascading" effects, offered the most disproportionate results for the effort expended – the most bang for the air power buck.[42]

The chief advocate for bombing the German transportation network in northwestern Europe was Lord Solly Zuckerman.[43] A South African specialist in zoology trained at Oxford, Zuckerman was first commissioned by the British Ministry of Home Security to determine the physical impacts of bombs on the human body. Zuckerman later put this biological expertise on bombing's effects to use in the Mediterranean theater, first in assessing Allied bombardment of Tripoli, and then in

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lords, rarely changing their conventional views or other personal allegiances. What mattered was the ability to destroy." Solly Zuckerman, *From Apes to Warlords: An Autobiography, 1904-1946* (London: William Collins Sons & Co. Ltd., 1988), 353.

[42] On the nonlinear nature of the objectives of the Transportation Plan, see especially Edward R. Smith, *Effects Based Operations: Applying Network Centric Warfare in Peace, Crisis, and War* (Washington, D.C.: NDU Press, 2002), 304 ff.

planning an experimental bombing campaign on the Axis-held island of Pantelleria between Tunisia and Sicily. The Italian garrison surrendered just before the arrival of Allied landing craft, elevating Zuckerman's standing with military commanders.[44] Success in Pantelleria led to Zuckerman's inclusion in planning for the invasion of Sicily, where he crafted the bombing of rail and road communications in Sicily and southern Italy.[45] In January 1944 Zuckerman came to London as an advisor to Leigh-Mallory, and the successful interdiction campaign in Sicily became the template for the AEAF's pre-invasion air planning in northwestern Europe.[46]

Zuckerman's "Transportation Plan" took shape in the meetings of the AEAF Bombing Committee and was first presented in an AEAF planning paper dated 22 January titled "Delay and Disorganization of Enemy Movement by Rail."[47] The proposal replaced an earlier SHAEF Joint Planning Staff plan for interdiction attacks against some twenty sites 50-60 miles behind the landing beaches a few weeks prior to the invasion that Zuckerman considered inadequate.[48] Instead, Zuckerman's plan called for a wider three-month campaign of attrition against seventy-six railroad facilities in France, Belgium, and western Germany to "paralyze the movement by rail of major reserves into

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[43] The best volume on Lord Zuckerman's contributions to strategic bombing is his lively, but somewhat prejudiced, autobiography *From Apes to Warlords.*

[44] On the Pantelleria air operation, see Edith C. Rogers, *The Reduction of Pantelleria and Adjacent Islands, 8 May – 14 June 1943*, USAF Historical Study No. 52 (1947). AFHRA microfilm reel no. K1007. See also Davis, *Carl A. Spaatz*, 225-239; Zuckerman, *From Apes to Warlords*, 181-196; and Arthur Tedder, *With Prejudice: The War Memoirs of Marshal of the RAF Lord Tedder* (New York: Little Brown, 1966), 440-443.

[45] See especially Solly Zuckerman, "Air Attacks on Rail and Road Communications: An Analysis of Operations Carried out in Sicily and S. Italy," 28 December 1943, AFHRA file no. 622.454-1, folder 1. See also Rostow, *Pre-Invasion Bombing Strategy*, 7-14; and Eduard Mark, *Aerial Interdiction in Three Wars* (Washington, D.C.: Center for Air Force History, 1994), 51-80.

[46] Charles P. Kindleberger, "Zuckerman's Bombs: World War II Strategy," *Encounter* (Nov 1978), 40.

[47] Rostow, *Pre-Invasion Bombing Strategy*, 14. Zuckerman later put the date when his plan was formally considered as 15 February 1944. Solly Zuckerman, "Bombs and Illusions in World War II: Lord Zuckerman Replies," *Encounter* (June 1979), 86. For a description of the Bombing Committee of the AEAF, see Zuckerman, *From Apes to Warlords*, 220.

France."[49] The plan's objective was to create a "railroad desert" in northwestern Europe. Doing this required the dedicated effort of less than half of the heavy bombers of RAF Bomber Command and slightly more than half of the American strategic bomber force for ninety days before D-Day.[50] Of the total pre-invasion bomb tonnage, the proposed plan assigned forty-one percent to transportation targets, eleven percent to POINTBLANK operations, with the remainder left for the destruction of airfields and coastal defenses.[51]

Zuckerman put less technological faith in precision bombing than his American counterparts. His study of the "hard practical lessons" of Pantelleria and Sicily had convinced him that pinpoint bombing accuracy was not only impossible, but also unnecessary. Zuckerman preferred area attacks against the sprawling railroad marshalling yards that held concentrations of vital equipment as well as control and repair facilities.[52] While a near miss on a bridge or tunnel would have no effect on the disruption of rail traffic, a near miss on a rail yard might still result in some degree of damage to track and essential facilities.[53]

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[48] Mets, *Master of Airpower*, 199-200.

[49] Rostow, *Pre-Invasion Bombing Strategy*, 14. Zuckerman's plan was not entirely original. As early as December 1942, the "Advisory Committee on Bombardment" of the Committee of Operational Analysis had discussed a combined precision bombing campaign against critical railway facilities in support of an invasion of Western Europe. See "Minutes of Meeting of Advisory Committee on Bombardment, 22 December 1942," AFHRA file no. 118.151-1.

[50] Winston S. Churchill, *The Second World War*, vol. 5, *Closing the Ring* (New York: Bantam Books, 1951), 451. The 8th Air Force was assigned forty-five percent of the required bomb lift capacity, Bomber Command thirty-five percent, and the fighter-bombers of the 9th AF the remaining twenty percent. Davis, *Carl A. Spaatz*, 330.

[51] Davis, *Carl A. Spaatz*, 333.

[52] Zuckerman, "Air Attacks on Rail and Road Communications," iv. See also Zuckerman, *From Apes to Warlords*, 407. An early American intelligence summary reached similar conclusions: "Marshalling yards are ideal targets for air attack." AAF Intelligence Service, "Air Intelligence Estimate: Transportation in Axis Europe," 1 December 1942, 26. AFHRA file no. 142.042-24.

[53] Solly Zuckerman, "Bombs and Illusions in World War II: Lord Zuckerman Replies," *Encounter* (June 1979), 86. Zuckerman favored large bombs and lots of them. "...[B]ombing military targets with too little strength was wasted effort." Zuckerman, *From Apes to Warlords*, 179. See also Rostow, *Pre-Invasion Bombing Strategy*, 11-12.

Using an analogy familiar to modern new scientists, Zuckerman (the biologist) compared a railway to a complex organism – bombing vital "railway centres" would generate secondary effects that would lead to paralysis of the entire system.[54] Railways, already operating at a considerable strain (a key assumption in Zuckerman's plan), were critical not only to the *Wehrmacht* but also to the German economy; attacks on marshalling yards would not only slow German military movements, but also halt industrial activity in the Reich. Transportation targets were both tactical objectives related to the success of OVERLORD as well as primary strategic targets *sui generis*.[55]

The most influential supporter of Zuckerman's Transportation Plan was Vice Chief Air Marshal Arthur Tedder, the Deputy Commander at SHAEF and "aviation lobe" of Eisenhower's brain.[56] For Tedder, marshalling yards were "common denominators" that could be hit for both operational and strategic effect by all types of aircraft, from fighters to heavy bombers, using both "area" and "precision" attacks.[57] Described by one historian as a "taciturn intellectual," Tedder was particularly impressed by Zuckerman's

[54] Zuckerman, *From Apes to Warlords*, 289-290. Zuckerman contrasts his own organic approach to the statistical, "quasi-economic" approach of his opponents. His favorite analogy for the transportation system was the circulatory system of the human body. See *ibid.*, 240.

[55] Zuckerman, *From Apes to Warlords*, 222. Zuckerman, in fact, considered these disruptive strategic effects to be more cost-effective than cutting specific lines of communication to achieve tactical effects, "[s]ince the strategical results...in general outweigh immediate tactical effects, and ... they can be achieved by a less costly air effort." Zuckerman, "Air Attacks on Rail and Road Communications," v.

[56] Churchill's phrase for Tedder's position supervising the Allied air effort. Tedder, *With Prejudice*, 510. See also Eisenhower to Tedder, 29 Feb 1944 in Alfred D. Chandler, Jr., *The Papers of Dwight David Eisenhower, The War Years: III* (Baltimore: The Johns Hopkins Press, 1970), 1755-1756 and Eisenhower to Tedder, 9 March 1944 in *ibid.*, 1765.

[57] Tedder distinguished between "point" targets and "common denominator" targets. Point targets represented objectives "from which crucial operations were controlled, or at which vital industries could profitably be attacked. Common denominator targets were "targets which were geographically dispersed, the destruction of which could cumulatively affect the whole war situation." Tedder, *With Prejudice*, 502. See also Alfred C. Mierzejewski, *The Collapse of the German War Economy, 1944-1945: Allied Air Power and the German National Railway* (Chapel Hill, NC: The University of North Carolina Press, 1988), 81-83.

"scientific" approach to aerial bombing.[58] Tedder's observation of the STRANGLE interdiction campaign in Italy in the spring of 1944 further reinforced his predilection for communications targets by demonstrating "that concentrated, precise attack upon railway targets scientifically selected would probably produce a degree of disruption and immobility which might make all the difference to the success or failure of the long awaited invasion of France."[59]

The formal alternative to AEAF's Transportation Plan was the "Oil Plan" from the USSTAF. Although Spaatz as commander of the USSTAF was the official sponsor of the Oil Plan, the plan originated from within his staff and from the Enemy Objectives Unit (EOU) at the American Embassy in London, the de facto target planning staff of the 8th Air Force. The EOU, headed by Charles P. Kindleberger, consisted primarily of economists from the Office of Strategic Services (including Walt Rostow and Carl Kaysen who later served as presidential advisors) who assisted the 8th Air Force in analyzing target systems in Germany.[60] Throughout the war, but particularly during the spring of 1944, the EOU was the link between intelligence and operations, the mechanism that translated theories of precision bombing into operational plans.[61]

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[58] Mierzejewski, *The Collapse of the German War Economy*, 81. "The clear and detailed reports submitted by Professor Zuckerman convinced me that this was the right method of attack." Tedder, *With Prejudice*, 489 and 503.
[59] Tedder, *With Prejudice*, 489. On the STRANGLE campaign in Italy, see especially F. M. Sallagar, *Operation "STRANGLE" (Italy, Spring 1944): A Case Study of Tactical Interdiction* (Santa Monica, CA: RAND, R-851-PR, February 1972). See also Mark, *Aerial Interdiction in Three Wars*, 141-178.
[60] See Economic Objectives Unit, *War Diary*, R&A Branch, OSS London, Vol. 5. AFHRA file no. 520.056-167. For a personal account of the EOU, see the unpublished memoir of Richard D. Hughes, AFHRA file no. 520.056-234. See also Rostow, *Pre-Invasion Bombing Strategy*, 15-23; Walt W. Rostow, *Concept and Controversy: Sixty Years of Taking Ideas to Market* (Austin: University of Texas Press, 2003), 30-58; Hansell, *The Air Plan That Defeated Hitler*, 148-149, and Davis, *Carl A. Spaatz*, 300. On the EOU's targeting philosophy, see Enemy Objectives Unit, "Handbook of Target Information," 24 May 1943. AFHRA file no. 118.042-2.
[61] EOU *War Diary*, 8.

When the first draft of Zuckerman's plan arrived at the USSTAF on 9 February, General Spaatz tasked General Charles Cabell, an operational commander drawn into planning, and Colonel Richard D. Hughes, the 8th AF's targeting liaison with the EOU, to study the plan and make recommendations concerning its feasibility.[62] USSTAF and the EOU saw several weaknesses in the Transportation Plan. Marshalling yards were an inherently more difficult target to hit precisely given their location, the haze and smoke that frequently blanketed the yards, and their sprawling size.[63] Furthermore, since there were many lines running through marshalling yards, damage could be quickly repaired. German military traffic represented only a small portion of French rail traffic, so there would have to be a major reduction of rail capacity before the bombing of rail yards reduced military traffic. Rail yards also tended to be located in city centers: "Attacks against the yards, especially those to be made by the RAF Bomber Command at night, would wreak havoc upon those non-enemy towns."[64]

Most importantly, the staff of the USSTAF and the EOU felt attacks against the rail yards would not draw out German fighter aircraft; Zuckerman's Transportation Plan would therefore allow the *Luftwaffe* a respite from the ongoing air superiority campaign. Spaatz' first priority had always been winning air superiority over the Luftwaffe, both to secure the immediate success of the invasion and to facilitate future strategic air operations.[65] Although the Transportation Plan listed air superiority as a priority, it said

[62] EOU *War Diary*, 91-93. Cabell, *A Man of Intelligence*, 109-110. On Hughes and his association with the EOU, see also Perrett, *Winged Victory*, 264 and 298; and Ronald Schaeffer, *Wings of Judgment: American Bombing in World War II* (New York: Oxford University Press, 1985), 74-75.
[63] Thomas I. Edwards and Murray A. Geisler, "The Causes of Bombing Errors as Determined from Analysis of Eighth Air Force Combat Operations," Headquarters, Army Air Forces, 15 July 1947, 41-43. AFHRA file no. 143.504-3.
[64] Cabell, *A Man of Intelligence*, 118.
[65] MacIsaac, *Strategic Bombing in World War II*, 76.

little about how to make this happen.[66] Whereas Leigh-Mallory thought the fight for air superiority would occur over the beaches, Spaatz felt the *Luftwaffe* had to be drawn into a fatal battle of attrition well before the event.[67] Attacking targets in Germany would take the fight to the German air force, foiling the new *Luftwaffe* strategy of conservation of strength. Strategic attacks against targets in the interior would also force the Germans to hold back some of their fighter strength that might otherwise oppose the Allied invasion, to say nothing of the continuing contribution to the wrecking of the German economy.[68]

Cabell and Hughes, with the help of the EOU, looked for alternatives to the Transportation Plan "where the destruction of the minimum number of targets would have the greatest, most prompt, and most long-lasting direct military effect."[69] Air planners had earlier rejected oil facilities as a target system as beyond their capabilities due to size and distance; after the successes against the *Luftwaffe* during Big Week in February 1944, this was no longer the case.[70] Cabell directed his planning staff that oil "be retained for full reconsideration because new conditions now prevailed." The available bomber force was now vastly larger and could be escorted by fighters all the way to the target, minimizing bomber losses. Additionally, with the 15th AF now operating from Italy, American bombers could strike at key German oil facilities around Ploesti, Romania.[71] Contingent on the changing operational environment, oil became the USSTAF's preferred target system.

Despite his personal preference for rail targets, the polished alternative plan presented to Spaatz on 5 March convinced him of the superiority of oil to transportation

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66 Zuckerman, *From Apes to Warlords*, 232.
67 Davis, *Carl A. Spaatz*, 307-312 and 355-357. Tedder, *With Prejudice*, 506.
68 Hansell, *The Air Plan That Defeated Hitler*, 236.
69 Rostow, *Pre-Invasion Bombing Strategy*, 22.

targets.[72] Striking at petroleum refineries and synthetic oil plants could be doubly effective, limiting fuel to German air and ground forces while engaging the German air force in a battle of attrition they could ill afford. Since destruction of a rail yard took the same tonnage of bombs as destruction of an oil facility and oil facilities were fewer, oil was also a more efficient economic target.[73] Furthermore, oil facilities, especially synthetic oil plants located away from populated areas, better fit the American penchant for discrimination and precision than Zuckerman's area attacks on rail yards.[74]

Economists from the EOU launched a "bureaucratic guerilla campaign" against the "scientific" data supporting the Transportation Plan that Zuckerman drew from the Mediterranean interdiction campaigns.[75] Contesting Zuckerman's methods, the EOU also disparaged the causal connections Zuckerman made between tactical events and strategic effects. "Science," as the head of the EOU later argued, "rests on controlled events, not observation of separate events in isolation."[76] Although the coal shortage in Sicily and Southern Italy happened simultaneously with attacks on rail yards, cause and effect could only be presumed, not proven.[77] Furthermore, any conclusions drawn from Italy could not be directly extrapolated, as the situation in Italy was unlike that in either

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[70] EOU *War Diary*, 59 and 83-84. Mets, *Master of Airpower*, 206-207. Craven and Cate, 3, 173.
[71] Cabell, *A Man of Intelligence*, 113.
[72] Cabell, *A Man of Intelligence*, 114.
[73] Mets, *Master of Airpower*, 204.
[74] The downside was that this meant that they required visual bombing weather since they could only be reliably located and hit using visual means. Davis, *Carl A. Spaatz*, 346.
[75] Rostow, *Pre-Invasion Bombing Strategy*, 36-43; and Mierzejewski, *The Collapse of the German War Economy*, 83-85. Zuckerman was highly critical of the "*a priori*" nature of the supposedly scientific approaches of his opponents in the USSTAF. Zuckerman, *From Apes to Warlords*, 354.
[76] Charles P. Kindelberger, "Zuckerman's Bombs: World War II Strategy," *Encounter* (November 1978), 40.
[77] Mierzejewski, *The Collapse of the German War Economy*, 82.

France or Germany. The railway network in Western Europe was much more extensive than in Sicily and Italy and would therefore take a comparably greater effort to disrupt.[78]

In place of Zuckerman's post-operation reports from Sicily and Italy, American planners drew upon "friendlier" information from operations in the Mediterranean theater.[79] Operation STRANGLE, the ongoing interdiction campaign on the Italian peninsula, in particular, seemed a more worthwhile case since it included attacks on all aspects of the transportation system to include bridges.[80] The EOU had worked since 1942 preparing some 285 "aiming point reports" that pinpointed precision strike locations for optimal bombing effects and took exception with Zuckerman and Tedder's lack of faith in precision bombing and their belief that bridges were too difficult a target.[81] The lessons of Sicily and Italy, insisted the EOU, showed the importance of bridges and the relative ease with which they could be destroyed.[82] A special AAF evaluation board in the Mediterranean theater that also highlighted bridges as a true "bottleneck" target in the transportation system further encouraged putting bridges before marshalling yards.[83] Interdiction attacks against bridges were a more efficient "diversion" of bombing

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[78] British Bombing Survey Unit, *The Strategic Air War Against Germany 1939-1945*, (London: Frank Cass, 1998), 113

[79] Mierzejewski, *The Collapse of the German War Economy*, 78-79. Rostow, *Pre-Invasion Bombing Strategy*, 36 and 40-41.

[80] Davis, *Carl A. Spaatz*, 385-386. Spaatz himself traveled to Italy in May to observe firsthand the effects of the STRANGLE campaign. Mark, *Aerial Interdiction in Three Wars*, 234-235.

[81] EOU, *War Diary*, 32. Rostow, *Pre-Invasion Bombing Strategy*, 21-22 and 38. Rostow, *Concept and Controversy*, 31-32. "Railway and road bridges are uneconomical and difficult targets, and in general do not appear to be worth attacking except where special considerations demand it in the tactical area." Zuckerman, "Air Attacks on Rail and Road Communications," v and 56-60. Although the Transportation Plan did call for "destruction of specific bridges affecting the assault area," Allied bombers were to target bridges only in the days immediately preceding the invasion because of the need for operational security and the ease with which bridges could be repaired. Zuckerman, *From Apes to Warlords*, 233. See also Tedder, *With Prejudice*, 531 and Charles Kindleberger and W. W. Rostow, "The Controversy over World War II Bombing," *Encounter* (Aug-Sep 1980), 100-102.

[82] "Bombing of Italian Railroads," 8 February 1944 in EOU *War Diary*, 102-103. See also Rostow, *Pre-Invasion Bombing Strategy*, 57-58. "It was a serious mistake of Zuckerman," wrote the Chief of the EOU, "to insist that railroad bridges could not be destroyed, as shown by Italian experience, when it was not tried." Kindleberger, 40.

resources than attrition attacks on rail yards: "[I]f the railway system were economically paralyzed by the destruction of the bridges then there would be enough surplus effort remaining available to destroy the oil industry...."[84] Furthermore, bridge attacks would be best carried out by fighters and medium bombers, freeing up the heavies for the strategic campaign.

Based on their belief about the efficiency of interdiction of bridges and individual rail lines, the EOU prepared a tactical plan to supplement USSTAF's strategic plan for attacks on German oil targets.[85] To avoid the diversion of air resources from the strategic campaign, the plan proposed destroying key bridges "at the desirable time," i.e., not until the last three weeks in May. Spaatz, obsessed with the strategic air war, chose to lay only the Oil Plan in front of Eisenhower, fatally weakening his argument against the Transportation Plan which more holistically addressed both tactical and strategic aspects.[86] Decision makers choosing between the Transportation Plan and the Oil Plan therefore faced what Walt Rostow called "a choice between false alternatives." In reality, the Allied air forces now had the resources available to do both.[87]

Vice Air Marshall Sir Arthur Harris and his RAF Bomber Command also opposed the Transportation Plan, but for different reasons. Harris opposed both transportation targets and what he called American "panacea" targets and the "oily boys" who supported them, arguing that Bomber Command could contribute more effectively by continuing its nighttime area offensive against German cities. "[C]learly the best and

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[83] Mierzejewski, *The Collapse of the German War Economy*, 79.
[84] Hughes, unpublished memoir, 46.
[85] EOU *War Diary*, 103-104.
[86] EOU *War Diary*, 105. Hughes, unpublished memoir, 47. A version of the EOU's tactical plan was eventually submitted to SHAEF in April as an alternative to the Transportation Plan. See "Plan for the Employment of the Strategic Bomber Force Prior to Overlord," 4 April 1944, AFHRA file no. 512.318-1.
[87] Rostow, *Pre-Invasion Bombing Strategy*, 72. See also EOU *War Diary*, 93.

indeed the only efficient support which Bomber Command can give to OVERLORD is the intensification of attacks on suitable industrial centres in Germany."[88] Harris felt the precision required to destroy transportation targets was beyond the capabilities of his force: "[T]here was little reason to think that the whole force could be rapidly switched to the destruction of small targets; on the contrary, all previous experience had gone to show that the R.A.F.'s heavy bombers ... could not operate by day in the face of any serious opposition, and could not hit small targets by night except when the opposition was negligible and the weather and light exceptionally good."[89]

Two events, however, swung Harris' vote to the side of the Transportation Plan. The first was a series of raids in France designed to test Bomber Command's capabilities against transportation targets.[90] On 6 March, British bombers employing new "master bomber" techniques aided by moonlight reflected off a nearby lake easily identified and successfully attacked the railway center at Trappes, leaving the yards there unusable for a month.[91] Harris was surprised by the accuracy of his bombers: "I myself did not anticipate that we should be able to bomb the French railways with anything like the precision that was achieved."[92] Subsequent tests in March gave additional "concrete evidence" of the effectiveness of night attacks on rail yards, further undermining Harris' opposition. The successful raids also confirmed the validity of the Transportation plan

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[88] Harris, 27 January 1944, in Lacey-Johnson, *Point Blank and Beyond*, 244. In January, Harris still thought Germany could be subjected to "a state of devastation in which surrender is inevitable" by the beginning of April. Harris quoted in Hastings, *Overlord*, 40.

[89] Harris, *Bomber Command*, 196. See also Arthur Harris, "Comments on Bomber Command Memorandum for the Employment of Night Bombers in Connection with 'Overlord,'" in Lionel Lacey-Johnson, *Point Blank and Beyond* (Shrewsbury, England: AirLife Publishing Ltd, 1991), 239-244.

[90] The six railway objectives selected "to provide data for the final detailed planning of 'Overlord'" were the yards at Trappes, Aulnoye, Le Mans, Amiens, Courtrai, and Laon. The air directive to Bomber Command is in Webster and Frankland, 4, Appendix 8, 165-167. See also Mierzejewski, *The Collapse of the German War Economy*, 84; and Webster and Frankland, 3, 27ff.

[91] The Trappes attack is described in detail in Lacey-Johnson, *Point Blank and Beyond*, 57-63. On British methods for improving the accuracy of their bombing, see also *ibid.*, 35-39.

in the mind of Tedder: "Our capacity to undertake precision bombing ... now made it possible for us to advocate with confidence a programme which entirely depended on the accurate delivery of bombs. Once this was understood, the complexities became less hard to resolve."[93]

The second event that swayed Harris was the poor performance of Bomber Command against night fighters over Germany. In the midst of losing the nighttime "Battle for Berlin," Harris came to see attacks against less heavily defended targets in France and Belgium as a respite for his weary aircrews. Spaatz, fairly bitter over the loss of an ally, later told Zuckerman that Harris found salvation in the chance to destroy railroad targets instead of continuing the failing night campaign against German cities.[94]

The military debate over the pre-invasion use of the bombers came to a head at the 25 March meeting of key commanders including Eisenhower and the Chief of the British Air Staff, Marshal Sir Charles Portal.[95] With the invasion quickly approaching, Eisenhower's main concern was the damage that might be done to the Allied cause should OVERLORD fail. Ensuring the success of the invasion was therefore of utmost priority.[96] Eisenhower recognized the value of strategic attacks, but nevertheless felt that any air plan could take account of POINTBLANK's strategic objectives only "so far as they were consistent with our great need for preparing for OVERLORD."[97]

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[92] Harris, 266.
[93] Tedder, *With Prejudice*, 513.
[94] Zuckerman, *From Apes to Warlords*, 352. See also Cabell, *A Man of Intelligence,* 119-120.
[95] "Final Minutes of a Meeting Held on Saturday March 25th to Discuss the Bombing Policy in the Period Before 'Overlord'," AFHRA file no. 512.318-1. This file also contains Spaatz' request dated 30 March 1944 for revision of the minutes to include his brief on the benefits of the Oil Plan as well as his express criticism of the Transportation Plan. The minutes are also in Rostow, *Pre-Invasion Bombing Strategy,* 88-98.
[96] Eisenhower, *Crusade in Europe*, 222.
[97] *The Eisenhower Diaries*, 114-115.

Transportation targets, not strikes against cities or oil, offered the most direct means of supporting ground forces in Normandy. Eisenhower and staff had more difficulty envisioning the less direct effects of Spaatz' Oil Plan.[98] As Spaatz himself admitted to Eisenhower, "There is ... no quantitative measure of either, although the fact that the rail attack will have some effect is more apparent."[99] Most important was the issue of timing and the lag between bombing and its frontline effects.[100] Although attacks against the sources of enemy strength deep in Germany might in the end be more disruptive and complete, it would take some time to fully realize these effects.[101] As Tedder quickly pointed out, attacks on synthetic oil plants "could not vitally affect the enemy's efforts in time for 'Overlord'."[102] Whereas Spaatz could not say for sure how long it would take for oil attacks to affect frontline German forces, advocates of the Transportation Plan promised that cutting lines of supply and communication would cause immediate tactical effects.[103] As Cabell later recalled, "[H]ere was the weakest point in our case."[104] The choice facing Eisenhower and the staff at SHAEF, then, was to either wait for the indirect and uncertain effects of a strategic bombing campaign or to order a more direct tactical/operational interdiction campaign whose effects could be

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98 MacIsaac, *Strategic Bombing in World War II*, 19.

99 "...it appears that too great a price may be paid merely for a certainty of a very little." Spaatz to Eisenhower, 31 March 1944, in Rostow, *Pre-Invasion Bombing Strategy*, 113-115.

100 Notes accompanying early drafts of FM 100-20: *Command and Employment of Air Power* show that the issue of delayed effects was on the minds of doctrine writers: "Knowledge of the time-lag is vital for a number of reasons. First of all, the time of land invasion must coincide with, not precede, the time of full effect of the bombing program. Secondly, if the effect of a bombing program is very long delayed, the chances that it will have any effect at all on the front-line strength are correspondingly diminished. Given enough time, the enemy can recover from anything." AFHRA file no. 248.211-1.

101 Mierzejewski, *The Collapse of the German War Economy*, 74-76.

102 Tedder, *With Prejudice*, 513.

103 Rostow, *Pre-Invasion Bombing Strategy*, 34.

104 Cabell, *A Man of Intelligence*, 119.

more easily "synchronized" with the coming ground invasion.[105] "[I]n default of any other alternative plan which would produce greater results," Eisenhower chose the Transportation Plan.[106] The Transportation Plan's certainty of timing and effects gave him a better sense of control over the invasion, even if these effects were more immediate and of lesser strategic impact.

As Portal and Tedder informed Eisenhower, "under the strict wording of the agreement" they could not legally place Bomber Command's bombers under the control of SHAEF until the British cabinet approved the plan.[107] When the air plan first went before the Defence Committee of the War Cabinet on April 3, Churchill expressed his misgivings about the potentially negative effects of civilian casualties in friendly occupied countries, casualties estimated as high as 160,000 by the Operational Research section of Bomber Command.[108] Churchill, with his keen appreciation for the wider impact of tactical and operational events, worried not just about the immediate consequences of civilian casualties – French hostility to the Allied invasion – but also

[105] Critics contend that Eisenhower fell back to the comfort of his Mediterranean experience where bombers had been solely at his disposal. As Haywood Hansell notes, "...although General Eisenhower had a considerable force of heavy bombers at his command [in the Mediterranean], he had no directive or obligation to use them in air warfare in furtherance of the Strategic Air War described in the Casablanca Directive. He used his heavy bombers in support of his surface mission, and as a result became strongly imbued with the conviction that this was their proper role." Hansell, *The Air Plan That Defeated Hitler*, 152. See also 186 and 237-239. See also Eisenhower to Arnold, 23 January 1944 in *The Papers of Dwight David Eisenhower, The War Years: III*, 1677.

[106] Minutes of 25 March meeting, Rostow, *Pre-Invasion Bombing Strategy*, 92.

[107] *The Eisenhower Diaries*, 115.

[108] "You will smear the good name of the Royal Air Force across the world." Churchill quoted in Terraine, 622. On the discussion of possible French casualties, see especially Zuckerman, *From Apes to Warlords*, 246-258. After Portal brought up these estimates at the 25 March meeting, Eisenhower left the matter for the political authorities to decide. Tedder, *With Prejudice*, 521; Rostow, *Pre-Invasion Bombing Strategy*, 88; and David Eisenhower, *Eisenhower at War*, 189-190.

about the "lag effects" of collateral damage. The French might end up more kindly disposed to the Russians than the British and Americans after the war.[109]

To both Tedder and Zuckerman's dismay, it was Zuckerman's own "scientific" formulas that were used as the basis for the exaggerated estimates of likely French casualties.[110] Spaatz and his staff quickly took advantage of the exaggerated figures to extend the fight against the Transportation Plan, discretely feeding information about potential civilian casualties to Churchill.[111] With the majority of the War Cabinet on his side, Churchill told Eisenhower, "the German Air Force should be the main target."[112] Eisenhower replied that not relying on "our overpowering air force" would be "extremely hazardous, if not foolhardy" as the success of the invasion depended upon carrying out attacks on transportation.[113] Still troubled that air power could take "so cruel and remorseless a form," Churchill took the issue back to the War Cabinet where it was recommended that the French themselves should be consulted.[114] MG Pierre Joseph Koenig, DeGaulle's representative in London, made it clear that imprecision was acceptable when the objective was important enough: "This is war, and it must be

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[109] Eisenhower, *Crusade in Europe*, 232-234. Tedder, *With Prejudice*, 524. Churchill feared that indiscriminate bombing might bring about "a great revolution in French feeling toward their approaching United States and British liberators. They may leave a legacy of hate behind them." Churchill to Roosevelt, 7 May 1944, in Churchill, *Closing the Ring*, 452.

[110] Zuckerman's corrected estimates were 12,000 killed and 6,000 seriously wounded, down from the Joint Intelligence Committee's original estimate of 40,000 killed and 120,000 wounded. The exaggeration of French casualties "seemed more like a deliberate effort to find an additional argument against the A.E.A.F. plan" to Zuckerman. Zuckerman, *From Apes to Warlords*, 246-252. See also Craven and Cate, v. 3, 79.

[111] Davis, *Carl A. Spaatz*, 400-402. Although collateral damage was a useful weapon in the fight against the Transportation Plan, the Deputy Chief of Operations for USSTAF, General Fred Anderson, in a letter to Portal admitted the limits of precision bombing and the impossibility of avoiding civilian casualties in attacks on rail targets in France. Conrad C. Crane, "The Evolution of US Strategic Bombing of Urban Areas," *The Historian* 50/1 (1987), 25.

[112] Churchill to Roosevelt, 7 May 1944, in Churchill, *Closing the Ring*, 452.

[113] Eisenhower to Churchill, 5 April 1944 in *The Papers of Dwight David Eisenhower, The War Years: III*, 1809. Also in Churchill, *Closing the Ring*, 451-452. See also Eisenhower to Churchill, 2 May 1944 in *ibid.*, 1842-1845.

[114] Tedder, *With Prejudice*, 528-530.

expected that people will be killed. ... We would take twice the anticipated loss to be rid of the Germans."[115]

With tacit French approval and preliminary RAF raids that demonstrated lower than expected civilian losses, the War Cabinet loosened their opposition to the Transportation Plan.[116] More than a month and a half after Eisenhower's acceptance of the plan, Churchill took the matter to Roosevelt, who himself stood in the midst of a rising tide of American public sentiment against civilian casualties from bombing.[117] Roosevelt's reply on 11 May nevertheless left little doubt about his support for the plan – although "every possible care [should be taken] to minimize civilian casualties," military considerations had to predominate.[118] With less than a month left before the invasion, the Transportation Plan had won its final approval.

The Plan (in practice)

Combined directives tasked the air forces to drop 45,000 tons of bombs on more than seventy targets in the German transportation system to "give the maximum possible assistance on the ground preparatory to the actual assault." The 8th Air Force was given responsibility for twenty-three transportation targets in Belgium, northwestern France, and central Germany; the 15th Air Force was to attack twenty-two targets in southern

[115] Tedder, *With Prejudice*, 531-533. General Walter B. Smith commented that Koenig took "a much more cold-blooded view than we do." Pogue, *The Supreme Command*, 132. See also Russell, *Leaping the Atlantic Wall*, 12.
[116] By 13 April, attacks on 13 attacks on French railway targets had killed 549 and injured 873 civilians (as reported by Radio Paris). Tedder, *With Prejudice*, 525-526.
[117] In March 1944, twenty-eight activists endorsed an anti-bombing article in the Christian magazine *Fellowship* that drew a front-page story in *The New York Times* the following day. Undersecretary of War for Air Robert Lovett then flew to Europe to visit AAF leaders to alert them of the problem of adverse publicity at home. Ronald Schaffer, "American Military Ethics in World War II: The Bombing of German Civilians," *The Journal of American History* 67/2 (Sep 1980), 323. See also Crane, *Bombs, Cities, and Civilians*, 28-31.
[118] Roosevelt to Churchill, 11 May 1944, in Churchill, *Closing the Ring*, 452-453.

France and Germany; and Bomber Command was responsible for twenty-seven targets in northwestern France and Germany. These targets were in addition to another thirty targets across Belgium and northern France already assigned to the tactical aircraft of the 9th AF and the AEAF after their release from the 8th Air Force's strategic bombing campaign.

Although it centered on attacks against transportation, the approved plan was in fact a compromise between the competing alternatives for the strategic bombers in support of the invasion.[119] The destruction of the German air force remained the first priority of the combined air forces. Just as the 8th AF was permitted to continue its attacks against aircraft installations in Germany, the military directive issued to Spaatz and Harris on 17 April (with the political debate over civilian casualties still ongoing) also allowed Bomber Command to continue its night offensive against German cities.[120] All-told, only forty-two percent of the total tonnage dropped by all Allied air forces in preparation for OVERLORD was directed against transportation targets (thirty-two percent by aircraft based in Britain and sixty-three percent by those in the Mediterranean).[121]

The plan was not only a compromise, but also (according to Rostow) a "decision that did not stick."[122] Although Eisenhower approved the Transportation Plan, Spaatz nevertheless found ways to execute the Oil Plan.[123] Despite having lost the argument,

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[119] Mierzejewski refers to the decision as an "unstable compromise." Mierzejewski, 61.
[120] The preliminary 17 April 1944 directive is in Webster and Frankland, v. 4, Appendix 8, 167-170.
[121] Office of the Assistant Chief of Air Staff, Intelligence, "Estimates of Effect of Air Attack on Axis Transportation," 17 June 1944, 2. AFHRA file no. 142.042-24, v. 2.
[122] Rostow, *Pre-Invasion Bombing Strategy*, 72.
[123] "We had no intention of using the Strategic Air Forces as a mere adjunct to the Tactical Air Command. On the contrary, we were most anxious to continue the destruction of German industry with emphasis upon oil. General Spaatz convinced me that, as Germany became progressively embarrassed by her diminishing

Spaatz and the USSTAF continued to raise issues like crew morale, civilian casualties and bridge busting to prolong the debate. The compromise command organization that put Tedder, and not Leigh-Mallory and the AEAF, in charge of the execution of the plan gave Spaatz the needed room to maneuver.[124] In a 31 March memo to Eisenhower (copied to Portal), Spaatz once again offered up oil facilities as a more lucrative target than rail lines in Germany proper. Employing a bit of subterfuge, Spaatz also requested that the 15th AF be allowed strike rail lines in Romania for the "interdiction of the transportation lines around Ploesti."[125] Ploesti was Spaatz' trump card, since damage to this crucial oil production facility would make it even more difficult to ignore the remaining synthetic oil plants in Germany.[126] In the ensuing "clandestine" oil offensive by the 15th Air Force, bombs directed "with more than coincidental inaccuracy" at the surrounding rail yards caused significant damage to Ploesti's oil facilities.[127] Eisenhower's lenience with Spaatz left open the door for a dual offensive against both oil and transportation.

By late April it was apparent that German fighters would not expose themselves by challenging Allied bombers over the marshalling yards in France and Belgium. Spaatz, playing to Eisenhower's fears of enemy air power acquired in North Africa, went back to SHAEF for permission to use the strategic bombers against the German synthetic

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oil reserves, the effect upon the land battle would be most profound and the eventual winning of the war would be correspondingly hastened." Eisenhower, *Crusade in Europe*, 222.

[124] Craven and Cate, v. 3, 78-81.

[125] Spaatz to Eisenhower, 31 March 1944, in Rostow, *Pre-Invasion Bombing Strategy*, 113-115. See also Cabell, *A Man of Intelligence*, 124; and Pogue, *The Supreme Command*, 130.

[126] Davis, *Carl A. Spaatz*, 389. "If Ploesti should be taken or neutralized, that would justify attacks upon the synthetic plants in Germany in preference to any other targets, for they would then become the sole source of refined products." Spaatz to Eisenhower, 31 March 1944. In Rostow, *Pre-Invasion Bombing Strategy* 114.

[127] Craven and Cate, 3, 174.

fuel industry.[128] After Spaatz hinted that he might resign, Eisenhower gave verbal permission on the 19 April to strike oil targets during the next period of suitable weather, so long as the USSTAF fulfilled their obligations under the Transportation Plan.[129] After waiting for three consecutive days of good weather to maximize effects, the 8th Air Force bombed the synthetic oil production facilities at Brux, Merseberg, Bohlan, Zeitz, and Lutzkendorf on 12 May, a date *Reichsminister* Albert Speer later identified as a turning point in the war.[130] As Cabell of the USSTAF later recalled, "Thereafter, by almost common consent, oil was our major preoccupation. The rail attacks were pursued only when weather blocked the oil targets."[131] On 28 and 29 May a combined total of 1,756 heavy bombers again struck oil targets.[132] The raids, "like pushing a stick into a hornets' nest," proved Spaatz correct, drawing stiff resistance from German defensive fighters.[133]

There were other military and political "diversions" beyond Spaatz' persistent commitment to oil targets that competed for air resources. Primary among these was Operation CROSSBOW, the air campaign against German V-1 and V-2 production facilities and launching sites.[134] From 13 February to 30 March, USSTAF heavy bombers flew 1452 sorties against these targets.[135] On April 19 (just two days after

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[128] On playing to Eisenhower's fears, see Cabell, *A Man of Intelligence,* 122-123.
[129] Webster and Frankland, 3, 46-47. Hansell, *The Air Plan That Defeated Hitler*, 235-236. Hansell insists this compromise was responsible not only for the success of the invasion but also for winning the war.
[130] "On that day [12 May] the technological war was decided. ... [W]ith the attack of nine hundred and thirty-five daylight bombers of the American Eighth Air Force upon several fuel plants in central and eastern Germany, a new era in the air war began. It meant the end of German armaments production." Albert Speer, *Inside the Third Reich* (New York: Avon Books, 1970), 445. See also Craven and Cate, v. 3, 175-179.
[131] Cabell, *A Man of Intelligence,* 124.
[132] Arnold, "Second Report," 364. Craven and Cate, 3, 178.
[133] Perrett, *Winged Victory*, 300. See also Craven and Cate, 3, 176-177.
[134] On the debate over the CROSSBOW campaign, see Craven and Cate, 3, 84-106; Davis, *Carl A. Spaatz,* 428-432; and McFarland and Newton, "The American Strategic Air Offensive," 221-222.
[135] "Status of Air Prerequisites for Operation 'Overlord'," 29 March 1944, AFHRA file no. 142.042-13, v. 1, 15. In early 1944, almost half of the 8th AF's missions and more than half of the 9th's were against V-1 targets. Perrett, *Winged Victory*, 286. See also Pogue, *The Supreme Command*, 134-136. In the first five

issuing the formal directive for the Transportation Plan), Tedder, bowing to political pressure from the British cabinet, put CROSSBOW targets above both *Luftwaffe* and transportation targets in the list of air priorities.[136] Spaatz promised Tedder his heavy bombers would hit CROSSBOW targets the next time weather was suitable so long as the following two occasions remained open for attacks against oil.[137] Set against the political imperative of stopping the rain of vengeance weapons in England, the 8th Air Force dropped more tonnage in the spring of 1944 on CROSSBOW targets than on transportation targets in support of the invasion.

The need for operational security was another factor that distinguished the pure plan from its military reality. The bombing campaign was a key component of the Allied deception plan, Operation FORTITUDE. Air planners used bombers to reinforce the mistaken conclusion of German commanders that the invasion would come through the Pas de Calais.[138] For every target hit within the invasion area, the Allies bombed two outside to conceal the intended landing location. Allied aircraft were further restricted from striking bridges over the Loire until after D-day and did not strafe barrier construction workers on the Normandy beaches to maintain the secrecy of the landing site.[139] Additionally, Allied aircraft selectively hit German radar and signals nodes to limit the availability of information, again attacking two sites outside the invasion area

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months of 1944, the 8th AF flew 8,940 sorties against CROSSBOW targets. Lacey-Johnson, *Point Blank and Beyond*, 129-132. The official AF history conveys USSTAF's frustration with these "political" diversions. "The primacy in priority given the robot-bomb and rocket threat sometimes proved irksome to USSTAF." AAF HQ concluded that the CROSSBOW diversions "may well make the difference between success and failure in accomplishing our pre-OVERLORD objectives." Craven and Cate, v. 3, 102-103.

[136] Craven and Cate, 3, 102-103. Davis, *Carl A. Spaatz*, 390-391.

[137] Davis, *Carl A. Spaatz*, 393.

[138] Anthony Cave Brown, *Bodyguard of Lies* (New York: Harper & Row Publishers, 1975), 520-527. On pre-invasion bombing as an exchange of information, see especially Smith, *Effects Based Operations*, 308-311.

[139] Craven and Cate, 3, 158 and 169.

for every one within.[140] Although the deception diluted the effort against transportation targets, the combined effect was that German defenders "were utterly confounded about the nature and intentions of the invasion forces."[141] Given the various diversions, the 8th Air Force did not fly its first transportation mission until 27 April, and even then, only with a limited effort; the first "major mission" against rail centers occurred only on 1 May, barely a month before the invasion.[142]

Tactical military necessities of the invasion put other demands on strategic air power. In the three weeks prior to D-Day Allied aircraft flew missions against the 100 useable airfields within a 350-mile radius of the invasion beaches to insure air superiority. Most of these airfields were already unoccupied. To prevent their use during the invasion, the strikes cratered runways and destroyed surrounding facilities, a task well suited to the heavy bombers. The 8th Air Force flew its first airfield mission in the invasion area on 9 May and the flights continued through the end of May when ULTRA intercepts and strategic fighter sweeps confirmed that the Germans had no intention of moving their aircraft to forward operating bases.[143]

Other tactical priorities that drew off bomber strength included attacks against German supply depots and beach defenses. As D-day approached, the urgency of striking these 'tactical' targets increased; after 1 June, when control of the bombers went over to Leigh-Mallory and the AEAF, they became the primary focus of the Allied air effort.[144] With attacks on CROSSBOW targets, missions supporting the FORTITUDE deception plan, and tactical strikes against airfields, depots, and beach defenses there

[140] Brown, *Bodyguard of Lies*, 524-525. Russell, *Leaping the Atlantic Wall*, 15.
[141] Craven and Cate, 3, 172.
[142] Craven and Cate, 3, 153-154.
[143] Craven and Cate, 3, 162-166. McFarland and Newton, "The American Strategic Air Offensive," 224.

were in essence many air campaigns waged simultaneously, campaigns competing for air power resources which although steadily increasing, were still ultimately limited.

If these priorities limited the means available, there were other factors that limited the ways in which these means could be applied. The most significant of these were the measures taken to avoid civilian casualties in 'friendly' occupied countries. The British War Cabinet initially recommended that the Transportation Plan include only targets where there would be no more than 100-150 civilian casualties, but Tedder insisted that such a limitation would "emasculate" any air operations in support of the landings.[145] To calm the anxiety of British politicians, the plan at first banned transportation targets in major cities, a constraint Tedder later described as the source of "the main leak for military movements to Normandy."[146] Churchill agreed to lift the ban in April, but the LeBourget rail hub in Paris was not attacked until 4 June. To help clear civilians from the paths of the bombers, attacks were frequently announced over the BBC beforehand.[147] Allied leaders also banned attacks on moving trains, although these restrictions were also removed as D-day approached.

Spaatz added his own restrictions to improve the "precision" of his bombers, forbidding the 8th Air Force from using the inherently inaccurate H2X radar equipment and insisting that only the best lead bombardiers be used.[148] From May through August 1944, ninety percent of American strikes on fifty-five rail yards in France and the Low

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[144] Craven and Cate, 3, 166-170.
[145] Tedder, *With Prejudice*, 528-529. See also Eisenhower to Churchill (drafted by Tedder), 2 May 1944 in *The Papers of Dwight David Eisenhower, The War Years: III*, 1842-1845. Churchill's reluctant approval for the plan included the additional limitation that the casualty list in occupied countries did not exceed 10,000. Pogue, *The Supreme Command*, 131-132.
[146] Eisenhower to Churchill, 2 May 1944 in *The Papers of Dwight David Eisenhower, The War Years: III*, 1842-1845; Tedder, *With Prejudice*, 541; and Craven and Cate, 3, 152.
[147] British Bombing Survey Unit, *The Strategic Air War Against Germany 1939-1945*, 113. Lacey-Johnson, *Point Blank and Beyond*, 63.

Countries were visually cited. Americans also dropped leaflets when the targets were French towns and minimized the use of incendiaries. Incendiaries represented only .4% of the tonnage dropped.[149] Despite an intense Axis propaganda campaign that caused Churchill to doubt as late as 28 May that the air forces were doing more good than harm, these adaptations resulted in lighter than expected civilian casualties and collateral damage. Concern for civilian casualties, by limiting the freedom of action of the air forces, decidedly improved the "precision" of Allied bombing.

Tactical successes during the campaign further shaped its overall conduct. An experimental attack on 21 April by RAF Typhoons confirmed Spaatz' supposition that that smaller aircraft, not heavy bombers, were best suited to take out bridges.[150] An attack by eight P-47's on 7 May that dropped the bridge at Vernon into the Seine dispelled any remaining doubts about the capabilities of fighter-bombers.[151] Bridge bombing, the preferred tactical method of the EOU, became a major element of the campaign; by the end of May, medium bombers and fighters of the 9th Air Force had destroyed eighteen of twenty-four major bridges over the Seine from Paris to LeHavre and blocked the other six.[152] Bombing bridges also proved easier on the French population than bombing

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[148] Davis, *Carl A. Spaatz*, 382.
[149] Davis, "German Rail yards and Cities," 53-55. Davis argues that Spaatz' instructions "produced what was probably some of the most accurate American heavy bomber attacks in World War II." This was not the case, however, in later attacks against transportation targets located in Germany proper as Spaatz issued no directives against radar bombing or limiting collateral damage. See also Eisenhower, *Crusade in Europe*, 232-233 and *Sunday Punch*, 19.
[150] Davis, *Carl A. Spaatz*, 403-408. Spaatz, in fact, vetoed the use of heavy bombers against bridges during the campaign. Craven and Cate, 3, 156-159. See also Rostow, *Pre-Invasion Bombing Strategy*, 59; Mark, Aerial Interdiction in Three Wars, 236; and Zuckerman, "Bombs and Illusions in World War II," 87.
[151] EOU *War Diary*, 116; and Rostow, *Concept and Controversy*, 49-50. See also the discussion between Kindelberger, Zuckerman, and Rostow in *Encounter*. The dramatic attack on the Vernon bridge was observed first hand by Erwin Rommel. Perrett, *Winged Victory*, 298-299.
[152] Arnold, "Second Report," 366. Tedder, *With Prejudice*, 537.

marshalling yards. Less than 1000 French civilians were casualties in bridge attacks.[153] As events demonstrated, tactical aircraft – fighters and light and medium bombers flying against targets well within their operational range – were more precise instruments of air power than strategic bombers.

Other adaptations further improved the "precision" of Allied air power during the pre-invasion air campaigns. As General Arnold noted in his report to General Marshall:

> "The fighters also developed special bombing techniques. Only a fighter can swoop low and drop a bomb within the entrance of a railroad tunnel to collapse a mountain upon a railroad line, or glide in diagonally to skip a bomb into the piers of a great bridge or against the gates of a canal lock. P-38 Lightning fighter groups also developed a technique of precision high-altitude bombing, with their speed making enemy interception extremely difficult."[154]

In one innovative method of attack, fighter-bombers used their center drop tanks as makeshift incendiaries against moving trains.[155] With the marshalling yards only lightly defended, medium B-26 bombers began flying in much smaller formations, "a measure which sharply improved accuracy and consequently reduced the danger to civilians" by reducing "spillover" that resulted from large bomber formations.[156] The Allies also found that a mixture of fighters and bombers could be synergistic: as a commemorative history of the operation notes, "The combination of the bombers dropping 2,000-pound bombs and the fighters diving with 500-pound bombs proved devastating."[157]

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[153] Davis, *Carl A. Spaatz*, 408. An Army Air Forces Evaluation Board estimated that the rate of civilian deaths in attacks against rail yards was 9.4 tons of bombs per death, but in attacks against bridges it was 22.2 tons per death. AAF Evaluation Board in the European Theater of Operations, "Effectiveness of Air Attack Against Rail Transportation in the Battle of France," 1 June 1945, 164. AFHRA file no. 138.4-37. Davis, "German Rail Yards and Cities," 62, n. 1 argues that bridge attacks by the 8th and 9th Air Forces combined caused 2000 casualties.
[154] Arnold, "Second Report," 363.
[155] Russell, *Leaping the Atlantic Wall*, 12-13.
[156] Craven and Cate, 3, 151-153. See also Davis, "German Rail Yards and Cities," 54.
[157] Russell, *Leaping the Atlantic Wall*, 14.

Although the frequency of transportation attacks increased from April to May, overall bomb tonnage dropped reflecting the increased use of medium and fighter-bombers with smaller loads.[158] After a 20 May SHAEF intelligence report (written with the help of the EOU) purported that the bombing of marshalling yards was failing to slow German movement, air commanders turned increasingly to the tactical air forces.[159] During Operation CHATTANOOGA CHOO CHOO, almost 800 fighters of the AEAF swept across France while 500 long range fighters of the 8th Air Force descended on southern Germany in what their commander, General William Kepner described as "unorganized guerilla warfare."[160] The result was that daytime German rail traffic came to a virtual halt.[161] From 1 May to 6 June, the 9th Air Force flew more than 35,000 tactical sorties – over a thousand a day – against targets that included railroad yards, transport, and bridges.[162] These sorties, in addition to directly contributing to the success of the invasion, also gave fighter-bomber crews experience in hitting precision targets, a skill that proved essential in the follow-on ground campaign across France.[163]

Determining Air Power's Effects

Measured in terms of effort, pre-invasion bombing of the German transportation network exceeded Allied expectations. Zuckerman's plan called for 45,000 tons of

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158 "Estimates of Effect of Air Attack on Axis Transportation," 17 June 1944, 7.
159 EOU *War Diary*, 107. Craven and Cate, 3, 156.
160 Stephen L. McFarland and Wesley Phillips Newton, *To Command the Sky: The Battle for Air Superiority Over Germany, 1942-1944* (Washington, D.C.: Smithsonian Institution Press, 1991), 229. For the results of these attacks, see "Effectiveness of Air Attack Against Rail Transportation in the Battle of France," 45.
161 Before the negative assessment of the effects of bombing on marshalling yards, USSTAF had frowned on fighter sweeps in search of moving trains for fear of the civilian casualties that might result. Davis, *Carl A. Spaatz*, 409-410. Mark, 237.
162 See especially Robert H. George, *Ninth Air Force, April to November 1944*, USAF Historical Study No. 36 (1945). AFHRA microfilm reel no. K1005.
163 McFarland and Newton, *To Command the Sky*, 232.

bombs for transportation targets. In the event, the combined Allied air power system dropped more than 76,200 tons. Bomber Command alone dropped 46,000 tons on rail yards throughout France and Belgium. Although the 8th Air Force contributed only 13,000 tons to the destruction of rail yards, this was still more tonnage than had been assigned in the original plan.[164]

The operation also exceeded expectations when measured in terms of the effects that bombing created. According to the official Army Air Force evaluation of attacks on the transportation network, railway traffic in France fell from an index of 100 in January and February to sixty-nine in mid-May and then to thirty-eight by D-day.[165] On 9 February, 250 French trains sat idle on railway sidings; by 20 March, after Bomber Command's first attacks on French rail yards, the number rose to 540.[166] In May 1944 alone, more than 900 locomotives and 16,000 freight cars were destroyed in Western Europe.[167] More than fifty-one of the eighty rail centers eventually bombed sustained "Category A" damage – enough that they did not have to be struck again. Whether measured in terms of effort or effect, these quantitative indices pointed toward the operation's success.

Quantitative measures alone, however, are insufficient in weighing the strategic impact of air operations. One of the most important qualitative measures of success was the satisfaction of ground commanders expressed with preparatory support from the air. Shortly after the war, General Eisenhower wrote:

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[164] Craven and Cate, 3, 155.
[165] Craven and Cate, 3, 160. The effects of the operation on French railway traffic are detailed in "Effectiveness of Air Attack Against Rail Transportation in the Battle of France," AAF Evaluation Board in the European Theater of Operations, 1 June 1945, 65-95. AFHRA file no. 138.4-37. See also Ambrose, *Eisenhower*, 289 and Ambrose, *D-Day*, 97-99.
[166] Tedder, *With Prejudice*, 526.

"The Normandy invasion was based on a deep-seated faith in the power of the air forces, in overwhelming numbers, to intervene in the land battle. That is, a faith that the air forces, by their action could have the effect on the ground of making it possible for a small force of land troops to invade a continent, a country strongly defended... Without that air force, without the aid of its power, entirely aside from its anticipated ability to sweep the enemy air forces out of the sky, without its power to intervene in the land battle, that invasion would have been fantastic. ...Unless we had that faith in the air power to intervene and to make safe that landing, it would have been more than fantastic, it would have been criminal."[168]

General of the Army George C. Marshall was likewise pleased with the results of the pre-invasion air campaign:

"In the spring of 1944, three months before D-day, the Allied Air Forces, while still hammering at their strategic targets, began directly to prepare the way for the invasion. Through destructive attacks on key bridges and rail centers, the "invasion coast" was effectively isolated. As a result of this preparatory bombing, the ability of the enemy to shift reserves to the critical area was severely restricted. Since the outcome of an amphibious operation hinges on the relative ability of the opposing forces to build up strength in the critical areas, this air preparation was a decisive factor in the success of OVERLORD."[169]

Those subjected to the rain of bombs also acknowledged the success of the Allied air effort. Radio Paris, a channel for Axis propaganda, reported at the end of May: "The French railway system is in complete chaos. The Allies have successfully pulverized into rubble whole marshalling yards. They have destroyed countless locomotives and have made scores of railway stations unusable."[170] Ultra intercepts and statements from German prisoners indicated that the 8th Air Force's attacks in May had dramatically

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[167] Marshall, "Biennial Report", 182. "The effects of this phase of the air assault were enormous, for transportation and communications are the life arteries of a modern industrial state engaged in total war."
[168] General Eisenhower, 16 November 1945, quoted in Futrell, *Ideas, Concepts, Doctrine*, 1, 173. In his book *Crusade in Europe*, Eisenhower similarly noted the importance of air power to the invasion: "The virtual destruction of critical points on the main roads and railroads leading into the selected battle area was a critical feature of the battle plan." Eisenhower, *Crusade in Europe*, 230-231.
[169] General George C. Marshall, "Biennial Report of the Chief of Staff of the United States Army to the Secretary of War, June 1 1943 to June 30, 1945," in *The War Reports*, 183.
[170] Radio Paris broadcast, 23 May 1944. Tedder, *With Prejudice*, 535.

reduced German production, further limiting German movement.[171] To give but one example, the First SS Panzer Division made four detours traveling from the Ghent area to Normandy, finally arriving to meet the invasion ten days after the Allied landing.[172] The oil campaign also contributed to slowing German reaction to the invasion, although German dependence on coal, not oil as Allied analysts had mirror-imaged, to some extent muted its effects.

The various air campaigns waged concurrently throughout the spring of 1944 not only slowed German movement into the invasion area, but also afforded air superiority over the landing beaches. Here too, quantitative measures of both effort and effect showed success against the *Luftwaffe*. During the first 6 months of 1944, 6,813 bombers dropped 16,522 tons on aircraft factories; additionally 8,257 bombers dropped 21,268 tons on airfields and air parks. Bombers destroyed 1,914 first-line enemy aircraft in aerial combat and 1,682 on the ground. Escorting fighters destroyed another 1,696 in the air and 761 on the ground in strafing attacks.[173] In a more qualitative assessment, General Arnold wrote: "The *Luftwaffe* [on D-Day] was conspicuous by its absence. The imponderable had become ponderable. ... Nobody now doubted the meaning of the damage reports, photographs, figures, and percentages of the great air attack on the *Luftwaffe* in the 5 great days of February and the days that followed."[174]

The overall result of attacks on the German transportation network and the campaign for air superiority over the beaches was that the Allies, despite difficulties with

[171] Davis, *Carl A. Spaatz*, 399; and Cabell, *A Man of Intelligence*, 123. "The notion that liquid fuel was crucial to German industrial activity was wholly erroneous. ...more the result of projecting the image of their own economy onto that of Germany than careful intelligence analysis." Mierzejewski, 84.
[172] Arnold, "Second Report," 367. See also Zuckerman, *From Apes to Warlords*, 299 ff. and Tedder, *With Prejudice*, 578-579.
[173] *Sunday Punch*, 6.
[174] Arnold, "Second Report," 366.

artificial harbors, were able to build up military strength faster than the Germans could move forces forward to oppose the invasion.[175] Air operations in preparation for OVERLORD also contributed to other objectives beyond the immediate success of the invasion. Coal and food distribution across large areas of northwestern Europe became very difficult in May, seriously affecting the German war economy.[176] The post-war U.S. Strategic Bombing Survey noted that there had been not been a serious shortage of rail cars and locomotives even under the strain of the Russian campaign until the spring of 1944. The final report concluded: "The attack on transportation was the decisive blow that completely disorganized the German economy."[177]

The decisiveness of this blow was due at least in part to the increasing accuracy of bombing. According to the official Army Air Forces Evaluation Board report on the operation, 6-7% of bombs from RAF heavy bombers, 16-18% of bombs from the heavy bombers of the 8th Air Force, and 28-30% for the medium bombers of the 9th Air Force landed within 500 feet of the aiming point.[178] These figures showed less than "pickle-barrel" precision, but were nevertheless better than the bombing accuracy of earlier missions. The paucity of German defenses in the occupied countries contributed to better bombing precision since bombers could fly at lower altitudes and in smaller formations. Improved accuracy was also the result of favorable weather conditions during the campaign, the proximity of targets (allowing the use of navigation and targeting aids with limited range like Oboe and Gee), as well as the availability of Allied fighter cover.[179]

[175] See Harrison, *Cross-Channel Attack*, 224 and 230.
[176] "Estimates of Effect of Air Attack on Axis Transportation," 17 June 1944, 9.
[177] *The United States Strategic Bombing Surveys* (European War) (Pacific War), reprint (Maxwell AFB, AL: Air University Press, 1987), 30 and 31-33.
[178] "Effectiveness of Air Attack Against Rail Transportation in the Battle of France," 134-135.
[179] British Bombing Survey Unit, *The Strategic Air War Against Germany 1939-1945*, 44-48. See also Lacey-Johnson, *Point Blank and Beyond*, 35-39 and 233-236.

Greater accuracy was most importantly the consequence of successful adaptation – improvements in techniques, tactics, and procedures contributed more than technological developments or operational conditions to improvements in pre-invasion bombing. Nowhere is this more evident than in Bomber Command's transition from area to precision bombing. Using a combination of Pathfinder and "Master Bomber" techniques where an airborne controller gave "false wind" corrections to target markings placed by Pathfinder aircraft, RAF bombers became more accurate, and therefore more destructive.[180] As a consequence of their successful adaptations, Bomber Command took on an ever-increasing role in the campaign, receiving an additional twelve targets from the tactical air forces in May.[181] The combination of new tactical methods, the increasing skill of the bomber crews, and strict political limitations on indiscriminate targeting created what the British Bomb Survey Unit called "a new psychological attitude to precision bombing" in the Allied air forces that resulted in lower than expected civilian casualties.[182]

Although the overall success of air power was unambiguous, understanding the ways in which air power had succeeded was and is less straightforward. The conflicting conclusions of subsequent analyses reflect the difficulties of reducing the complex problem to its individual elements.[183] Those who advocated the Transportation Plan – Zuckerman, Leigh-Mallory, and Tedder – interpreted the various measures as indicators of the success of attacks on rail yards.[184] Those who opposed the Transportation Plan – primarily Spaatz and the EOU – thought the evidence showed the effectiveness of

[180] Terraine, *A Time for Courage*, 623; and Harris, *Bomber Command*, 202-203. On improvements in British nighttime precision bombing, see also Webster and Frankland, 3, 141-162.
[181] Craven and Cate, 3, 154-155.
[182] British Bombing Survey Unit, *The Strategic Air War Against Germany 1939-1945*, 18 and 47-48.

interdiction attacks and the less direct effects of attacks on German aircraft production and oil facilities.[185] At stake in this argument was the right to dictate targeting priorities once the heavy bombers were released from the control of the AEAF.

As analysts at the EOU noted, it was the interdependence of the problem that made sorting out cause and effect so difficult. "The various factors do not bear a simple additive relation to each other.... [T]hey operate at a number of different levels, and their functional relations are complex."[186] Although both sides in the argument acknowledged the irreducible "intermingling of effects," each nevertheless turned to reductionist methods to demonstrate the "decisive" contribution of their preferred method of attack in generating desired effects.[187]

Even before the invasion, the EOU was quick to publish assessments that argued bombing rail yards was less effective than interdicting individual rail lines. SHAEF G-2 published in May their "Interdiction Handbook" (with the help of the EOU) that "proved not only to be of considerable operational use, but good advertising for the conception of interdiction."[188] On 20 May and 7 June, two SHAEF intelligence reports (again written by a member of the EOU) argued the inadequacy of attacks on marshalling yards and the need to supplant these with tactical attacks on bridges and depots, as well as strategic

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[183] Webster and Frankland, 3, 245. See also Craven and Cate, 3, 160-162.
[184] See for example Zuckerman, *From Apes to Warlords*, 257-258.
[185] See for example Charles Kindleberger, "Interim Report on the Movement of German Reserves," 16 June 1944, in Rostow, *Pre-Invasion Bombing Strategy*, 122-137.
[186] EOU *War Diary*, 37-38.
[187] See Rostow, *Pre-Invasion Bombing Strategy*, ix-xi. Zuckerman's analysis of operations in Sicily shows a comparable awareness of the complexity of the problem: "The analysis of the problem is highly complicated by the very large number of variables it contains." Zuckerman, "Air Attacks on Rail and Road Communications," 1.
[188] EOU *War Diary*, 114-115. Enemy Objectives Unit, "Handbook of Target Information," 24 May 1943. AFHRA file no. 118.042-2.

attacks against oil and other targets in Germany.[189] The reports also asserted that the Transportation Plan was costing more to the French population than to the German military.[190] "Attack on rail centers," another Army Air Forces report concluded in June, "as an exclusive target system to affect military traffic has not been proven equal to attack on bridges and lines."[191]

But these early reports focused on statistical percentages of equipment destroyed, and not total functional effects.[192] According to American analysts, "At a maximum, military traffic comprised 25% of total German rail traffic while essential economic traffic comprised at least 50% of the total. Therefore, air attack must cut total traffic by as much as 75% to affect military traffic but essential economic traffic is affected after a 25% traffic reduction."[193] Zuckerman rightly accused the EOU and the USSTAF of linear methods in their calculations – of the use of basic subtraction in calculating the effects of bombing on railroad capacity.[194] "It was a simple 'one and one make two' stand, based on the assumption that the dislocation of a vast interlocking functional system such as a

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[189] EOU *War Diary*, 106-107. See "Estimates of Effect of Air Attack on Axis Transportation," 17 June 1944. AFHRA file no. 142.042-24, v. 2.

[190] "Estimates of Effect of Air Attack on Axis Transportation," 7 and 9. See also Craven and Cate, 3, 73.

[191] Office of the Assistant Chief of Air Staff, Intelligence Analysis Division, European Branch, "Evaluation of Transportation as an Air Target: A Summary of the European Experience," 15 June 1945, 3. AFHRA file no. 142-042-24, v. 4. See also Office of the Assistant Chief of Air Staff, Intelligence Analysis Division, European Branch, "Strategic Bombing of Axis Europe January 1943 – September 1944: Bomb Damage to Axis Target Systems," 15 November 1944, 39-40. AFHRA file no. 142.042-8.

[192] Harrison, *Cross-Channel Attack*, 224.

[193] "Evaluation of Transportation as an Air Target" 7.

[194] Zuckerman, *From Apes to Warlords*, 356. Earlier in the war, the EOU's "Handbook of Target Information" noted the unquantifiable nature of the problem, emphasizing the role of judgment in the final analysis: "The final stage of weighing all the target selection factors and deciding on an operational program cannot be handled by mathematical formula. To a marked extent it involves the element of judgment. ...The judgment factor may be required to fill gaps in factual data or to re-evaluate appraisals previously made. Or the balance may be turned by judgment concerning the intentions of the enemy, the relative degrees of disorganization likely to be created, or the manner in which the enemy is likely to react to the destruction of alternative targets. Considerations like these, as well as the most recent experience of our air force in attacking various types of targets, must be carefully weighed before a final target selection is made." Enemy Objectives Unit, "Handbook of Target Information," 24 May 1943. AFHRA file no. 118.042-2.

railway network could be assessed in terms of capacity."[195] Zuckerman the biologist, on the other hand, saw organic wholes. A comparatively small input such as the destruction of a single rail yard (or bridge) cascades throughout the system, as minor delays become major disruptions of the network.[196] The paralysis of the entire system did not require its complete destruction.

To counter the Americans' fallacious reasoning, Zuckerman established himself in Paris in the summer of 1944 on the heels of the Allied advance to conduct his own "scientific" analysis. While in Paris, Zuckerman and his staff had access to French railway personnel and records as well as captured German documents on the efficacy of rail transportation. French records showed (and German documents confirmed) a precipitous and nonlinear fall in rail movement beginning in March with the first attacks on the marshalling yards. By the end of May, the number of daily trains measured by wagon loadings had fallen to about one third their normal level. In the most heavily bombed areas in the north, rail traffic had fallen to twenty percent of normal by 26 May (before the Seine bridges had been dropped); by D-Day, it was thirteen percent of normal. Although damage to the rail network was limited, the effects of this damage were not: "[T]he capacity of the railways was so reduced and their state of disorganization so grave that even the highest priority military traffic could not be handled properly… Two or three months of bombing had in fact paralyzed the economic life of France."[197] Given these results, Zuckerman concluded that Allied air power could make its most effective

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[195] Zuckerman, *From Apes to Warlords*, 239.
[196] British Bombing Survey Unit, *The Strategic Air War Against Germany 1939-1945*, 120.
[197] Zuckerman, *From Apes to Warlords*, 289 and 300-301. See also Tedder, *With Prejudice*, 577-578; and British Bombing Survey Unit, *The Strategic Air War Against Germany 1939-1945*, 117.

contribution to hastening the end of the war by extending attacks on marshalling yards into Germany.[198]

Economists at the EOU, "in a conscious effort to recapture the scientific spirit," turned to quantitative cost-benefit analyses to further demonstrate the efficiencies of the combination of bridge and oil attacks.[199] Bombing rail yards with heavy bombers had failed to stop German military rail traffic; studies from both Normandy and the Mediterranean, on the other hand, showed interdiction by medium bombers and fighter aircraft had been extremely effective.[200] Freed from the obligations of both rail yard and bridge attacks, heavy bombers had had an even more positively nonlinear effect on the German oil industry. Although only 5,166 tons of bombs were dropped on oil facilities in May, production fell precipitously from 175,000 tons in April, to 156,000 tons in May, and then to 53,000 tons in June.[201] By July, hundreds of newly built German fighters sat on the ground for lack of fuel, effectively adding to the combat losses suffered defending German industry from Allied bombers.[202] As an Army Air Force Evaluation Board argued, "...even without the tonnage dropped on French rail centers before D-Day, as great a degree of interference with tactical traffic could have been achieved [by bridge attacks] as was actually achieved. Hence if this degree of interference is considered

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[198] Zuckerman, *From Apes to Warlords*, 289-290.
[199] EOU *War Diary*, 118. See Lytton, "Bombing Policy in the Rome and Pre-Normandy Invasion Aerial Campaigns of World War II" for an example of the economists' cost-benefits approach to bombing analysis. Rostow described the technical, statistical approach of the EOU as "something of the Austrian theory of capitalism and Leontieff." Rostow, *Pre-Invasion Bombing Strategy*, 22.
[200] See Lytton, "Bombing Policy in the Rome and Pre-Normandy Invasion Aerial Campaigns of WWII"; Kindleberger, "Zuckerman's Bombs;" and Rostow, "The Controversy Over World War II Bombing."
[201] Craven and Cate, 3, 179. Even Tedder admitted that "there was much to be said for the 'Oil Plan', though for the immediate purposes of 'Overlord' the Transportation Plan had to come first." Tedder, *With Prejudice*, 601-602. As Harris later wrote in describing the effects of the oil plan, "What the Allied strategists did was to bet on an outsider, and it happened to win the race." Harris, 232-234.
[202] Davis, *Carl A. Spaatz*, 323-326.

adequate, the pre-D-Day attacks against French rail centers were not necessary, and the 70,000 tons involved could have been devoted to alternative targets."[203]

These conflicting interpretations demonstrated the vulnerability of statistics to bias and the difficulties of quantifying both input – the effort required – as well as output – the effects these inputs generated – in the complex and nonlinear environment of war. Both sides (Zuckerman to a lesser extent than the Americans at the EOU) relied upon numbers and statistics, since they gave the appearance of concreteness and clarity to still cloudy causal connections. But quantifying the bombing problem slighted intangible "systemic" effects and synergies.[204] Estimates of the amount of effort required – like the Evaluation Board's table of bombing tonnage required to drop a bridge – or of expected effects – as in their somewhat grisly statistic on tons of bombs per death for unintended casualties in rail yard and bridge bombing – were only statistical averages of unique cases involving immeasurable combinations of operational factors.[205] The traditional scientific method and the quantification it entailed poorly fit the problem. As the Army Air Force Evaluation Board noted: "[A]ll the various kinds of targets were attacked at the same time, and hence the effects of the attacks were thoroughly intermingled in the resulting

[203] AAF Evaluation Board in the European Theater of Operations, "Summary Report on Effectiveness of Air Attack Against Railway Transportation in the Battle of France," 1 June 1945, 36. AFHRA file no. 138.4-37. See also Cabell, *A Man of Intelligence,* 128-129.
[204] For an example of quantification of the analysis, see especially Zuckerman's equation for "the number of vehicles which will be destroyed or damaged per acre" in rail yard attacks in Zuckerman, "Air Attacks on Rail and Road Communications," 45-47. See also Rostow's discussion of his regression analysis on the destruction of bridges in Rostow, "The Controversy Over World War II Bombing."
[205] "Effectiveness of Air Attack Against Rail Transportation in the Battle of France," 135 and 164. On quantifying bridge bombing, see the exchange between Kindelberger, Zuckerman, and Rostow in *Encounter*. See also Craven and Cate, 3, 157; Lytton, "Bombing Policy in the Rome and Pre-Normandy Invasion Aerial Campaigns of WWII," 54-56, and Harrison, *Cross-Channel Attack*, 228. On calculating civilian casualties, see Davis, "German Rail Yards and Cities," 54 and 62, n. 41; Craven and Cate, 3, 79; Tedder, *With Prejudice*, 536-541; and Lacey-Johnson, *Point Blank and Beyond,* 164-165.

decline of traffic. The exigencies of war did not permit a careful testing of each in separate trials."[206]

Proponents from both sides, intent on determining which element of the air campaign was more "decisive," also inadequately considered other inputs that were just as important to the results of the campaign. The Transportation Plan was not executed in isolation. The FORTITUDE deception, for example, probably immobilized more German units than did the bombing of roads and rails.[207] Similarly, the impact of the French resistance's sabotage of French railroads surprised Allied commanders after D-day and is still somewhat underappreciated today.[208] Outcomes in war are seldom determined by single causes. Bombing alone was a necessary, but not sufficient input. Thorough causal analysis must take into account not only targeting alternatives, but also other dynamics beyond the air campaign.

In evaluating the various alternatives for air power, it was necessary to consider not just the interdependence of causes, but also the interdependence of effects. "The effect of damaging depots, yards, bridges, or line," noted the Evaluation Board, "depends on what is happening to other parts of the system. ...When many parts of the system are attacked about the same time, the effects are not only interrelated, but they merge together and the joint effect can be measured only as a total result within a region or other

[206] "Summary Report on Effectiveness of Air Attack Against Railway Transportation in the Battle of France," 24. See also Sir Solly Zuckerman, *Scientists and War: The Impact of Science on Military and Civil Affairs* (New York: Harper & Row, Publishers, 1966), 20-21.
[207] Mark, *Aerial Interdiction in Three Wars*, 257. Rostow, *Pre-Invasion Bombing Strategy*, 124-125.
[208] On the contribution of the French Resistance to the destruction of the French railway network, see especially Harrison, *Cross-Channel Attack*, 198-207 and 408-410. See also Lacey-Johnson, *Point Blank and Beyond*, 154-160. A slow down program by French railway workers also contributed to the disruption of the transportation system in France both before and after D-Day. From an interview with the president of the French railway system, in 8th Air Force, "Bombing Results in the Paris Area, Sept. 7-13th, 1944," 14. AFHRA file no. 520.056-228.

large area."[209] The creation of a "railway desert" drove back German railheads, increasing the distance covered by motor transport and thereby magnifying the effects of the oil campaign.[210] Fighter sweeps then made road travel by day extremely hazardous.[211] Bombing rail yards also destroyed phone lines, forcing Germans to use radios, which indirectly assisted in gathering information about oil targets.[212] Attacks against oil facilities tied up German aircraft and anti-aircraft guns, facilitating unhindered attacks on French rail yards.[213] Rail yard, bridge, and oil attacks all aided both the CROSSBOW campaign against German missiles and the degradation of beach defenses as transport of men and equipment became more difficult and construction materials were diverted for the repair of broken rail lines and bridges.[214]

Allied air strategy was also contingent on German strategy, both on the ground and in the air. Attacks on the transportation network in France depended on the inadequacy of German policies. The French railway system, already weakened by Nazi expropriation of locomotives and the abuse of French railway workers, was vulnerable to aerial attack.[215] German preparations for the disruption of rail transport before the

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[209] "Effectiveness of Air Attack Against Rail Transportation in the Battle of France," 66.
[210] Zuckerman, *From Apes to Warlords*, 423. See also Tedder, *With Prejudice*, 537.
[211] Mark, *Aerial Interdiction in Three Wars*, 252-253. As Zuckerman noted about attacks in Sicily, "Major damage to the railway system ... forced the enemy to other means of transport, especially to the use of motor-transport, and helped to consume his petrol supplies." Zuckerman, "Air Attacks on Rail and Road Communications," ii-iii.
[212] Edward C. Mann, Gary Endersby, and Thomas R. Searle, *Thinking Effects: Effects-Based Methodology for Joint Operations* (Maxwell AFB, AL: Air University Press, 2002), 20-21.
[213] See Speer's report to Hitler on the effects of attacks on oil, 30 June 1944, in Webster and Frankland, 4, 321-325. "Most of the railway centres in France were defended by few anti-aircraft guns, and as a result we were often able to bomb from much below the cloud level. This, of course, made for increased accuracy of attack." Harris, *Bomber Command*, 203.
[214] Zuckerman, *From Apes to Warlords*, 301; British Bombing Survey Unit, *The Strategic Air War Against Germany 1939-1945*, 118; and Harrison, *Cross-Channel Attack*, 227-228.
[215] Craven and Cate, 3, 150.

invasion were inadequate.[216] Furthermore, the success of either the Transportation Plan or the Oil Plan was contingent on the Germans' choice between Rommel's strategy of defending the beaches or von Rundstedt's plan for the use of mobile reserves.[217] Although the "diversion" of bombers to targets in France and the Low Countries may have given the *Luftwaffe* a temporary respite, their failure to show against CROSSBOW and transportation attacks resulted in much lower casualty rates for the Allied strategic air forces, noticeably improving air crew morale during the trying months of March and April 1944.[218]

German reaction and adaptation during the air campaign meant that the effects of bombing were not simply cumulative in a linear fashion. Although German crews faced the doubled effects of increasing demands for repairs but a decreasing supply of repair materials and facilities thanks to rail yard attacks, they often managed to reopen broken rail lines within forty-eight hours of their destruction.[219] In April, the German military suspended leaves and placed restrictions on non-military traffic to reduce burdens on the railroads.[220] German authorities further attenuated the effects of the attacks by diverting traffic, constructing ferries, employing bridge repair trains, and building temporary spans

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[216] Mark, *Aerial Interdiction in Three Wars*, 236; Harrison, *Cross-Channel Attack*, 224-225; and "Summary Report on the Effectiveness of Air Attack Against Rail Transportation in the Battle of France," 28.
[217] See Directorate of General Purpose and Airlift Studies, Assistant Chief of Staff, Studies and Analysis, Headquarters, USAF, "The Impact of Allied Air Interdiction on German Strategy for Normandy," August 1969. AFHRA file no. K143.044-15. See also Mark, *Aerial Interdiction in Three Wars*, 216-220; and Robert E. Schmaltz, "The Impact of Allied Air Interdiction on German Strategy for Normandy," *Aerospace Historian* 17/4 (Winter 1970), 153-155.
[218] Craven and Cate, 3, 155; and Davis, *Carl A. Spaatz*, 379-384 and 396.
[219] SHAEF Weekly Intelligence Summary, No. 11, 3 June 1944. Referenced in Smith, *Effects Based Operations*, 347-348, n. 7. Transportation targets were perhaps less adaptable than other target systems. Unlike German factories, rail yards and bridges were not easily concealed and could not be dispersed or moved underground. Office of the Assistant Chief of Air Staff, Intelligence Analysis Division, European Branch, "Evaluation of Transportation as an Air Target: A Summary of the European Experience," 15 June 1945, 10-11. AFHRA file no. 142-042-24, v. 4.
[220] Harrison, *Cross-Channel Attack*, 227.

across rivers.[221] The effects of bombing, then, could only be calculated with German responses in mind.

The contingent and interactive nature of the pre-invasion air campaigns resulted in unforeseen consequences, both positive and negative. While Churchill feared a French population hostile to the Allies, the bombing had the unintended positive effect of raising French ire against the Germans – "the temper of the population, especially that of Paris, is rising because no food is available, nobody can travel, and there are severe restrictions in the use of electricity. Frenchmen are blaming the Germans for all the misery which has descended on France."[222] Another positive, yet unexpected consequence was the emergence of the 9th Air Force as a "strategic" force all its own.[223] The disruption of the transportation network in France had the negative unintended consequence of complicating the follow-on ground campaign. When Portal asked at the 25 March meeting of air commanders if the destruction of French railroads would slow Allied pursuit, Eisenhower responded: "We should not consider it. The Germans shall certainly destroy the railroads as they retreat."[224] But the same attacks that *efficiently* destroyed the German transportation network in France *effectively* slowed the subsequent Allied advance. Patton's famous "Red Ball Express" – the use of trucks, not trains, for the rapid advance of the Third Army – flowed as a consequence of the disruption of the rail

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[221] Kindleberger, "Interim Report on the Rail Movement of German Reserves," in Rostow, *Pre-Invasion Bombing Strategy*; and "Overlord - the Interdiction Campaign," 3-4. AFHRA file no. 142.042-4, v.1. After learning of the destruction of the Seine bridges in late May, *Reichsminister* Albert Speer immediately ordered the delivery of steel girders to hasten repairs and the construction of ten ferries and a pontoon bridge. Speer, *Inside the Third Reich*, 482.
[222] Radio Paris broadcast on 23 May 1944. Quoted in Tedder, *With Prejudice*, 536. Also in Brown, *Bodyguard of Lies*, 519.
[223] See especially Craven and Cate, 3, 121ff.
[224] David Eisenhower, *Eisenhower at War*, 189.

network across northern France.[225] That this could succeed only in an environment of Allied air superiority further speaks to the indivisible and interdependent nature of the variables of warfare.

The Indivisibility of Air Power

Opponents in the air power debates of 1944 disagreed over the effectiveness of proposed target systems. Plagued by the memory of scarce resources in 1942-1943, both sides saw only dispersion of effort in chasing too many targets.[226] But sticking exclusively to either the Transportation Plan or the Oil Plan would have sacrificed the synergies that emerged from the combined campaign.[227] In the new environment of abundance of 1944, effective strategy was not an "either-or" proposition, but a matter of combination, compromise, and adaptation.[228] Though airmen may have differentiated on paper, in reality the dividing line between tactical attacks with only local effects and strategic attacks with political and economic impact was never so clear. Air power, applied simultaneously, proved indivisible.[229] "Bomber" Harris may well have been correct about the American Oil Plan: "The Allies bet on an outsider and it happened to win the race."[230] Determining precisely which air power input won this race, however, is also beside the point.[231]

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[225] Rostow, *Pre-Invasion Bombing Strategy*, 156-157, note 43. Mark, 256. Mann, Endersby, and Searle, 36.
[226] Futrell, *Ideas, Concepts, Doctrine*, 1, 152; and Sherry, *The Rise of American Air Power*, 164. See also Hansell, *The Strategic Air War Against Germany and Japan*, 15; and Hansell, *The Air Plan That Defeated Hitler*, 256-259 on what he called the "unfortunate policy of 'scatterization'."
[227] MacIsaac, *Strategic Bombing in World War II*, 77; and Davis, *Carl A. Spaatz*, 326.
[228] Mierzejewski, *The Collapse of the German War Economy*, 67-68.
[229] "Before it is tactical or strategic, airpower is, simply, airpower...." Thomas Alexander Hughes, "Normandy: A Modern Air Campaign?" *Air & Space Power Journal* 17/4 (Winter 2003), 27. See also "The Strategic Bomber," *Air University Review* 8/1 (Summer 1955), 118-119
[230] Harris, *Bomber Command*, 232-234.
[231] See especially Mierzejewski, *The Collapse of the German War Economy*, 65-67.

"War," writes Clausewitz, "is never an isolated act."[232] Strategic effects were dependent on the synergy of the combined campaigns and complicating military and political factors beyond the effective control of airmen.[233] Although military scientists seek precise measures of both causes and effects in planning and analyzing air campaigns, the complex and nonlinear nature of the event makes such "precision" problematic at best.[234] Given changing operational conditions often recognized only qualitatively, a holistic analysis of air targeting and its resulting effects should involve more than just numbers. Although quantitative yardsticks may be useful in apportioning scarce resources, military planners should guard against the excessive and unthinking use of these yardsticks for assessing and solving the continuously evolving problems of air warfare. The new sciences metaphor, with its more qualitative understanding of the interdependent and emergent nature of complex phenomena, may offer airmen a useful remedy for this affliction.

In the language of the new sciences, the pre-invasion air campaigns represented a bifurcation point between the reductionist strategic doctrine of high-altitude precision daylight bombing and a more holistic schema for air power that included fighters, fighter-bombers, and medium bombers. The technological products of the war suggested two distinct possibilities for a future air power, offering instruments of greater precision –

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232 Clausewitz, *On War*, 78.

233 Airmen celebrate Field Manual 100-20: *Command and Employment of Air Power*, which grew out of the disastrous performance of air power decentralized under Army commanders in North Africa in 1943, as a declaration of operational autonomy for the air forces. But in less celebrated passages, FM 100-20 concedes that independent, strategic air power may sometimes be diverted to the tactical task of supporting the land forces. "Although normally used against [strategic objectives], when the action is vital and decisive, the strategic air force may be joined with the tactical air force and assigned tactical air force objectives." FM 100-20: *Command and Employment of Air Power*, 21 July 1943. AFHRA file no. 248.211-64.

234 See Smith, *Effects Based Operations*, 356-373; Mann, Endersby, and Searle, *Thinking Effects*, 36; and Lacey-Johnson, *Point Blank and Beyond*, 175. On the uncertainties introduced by interaction, see

radar bombing and bombsights, electronic navigation aids, and pilotless guided bombs – as well as instruments of less discriminate destruction – nuclear weapons. Entering the Cold War, American airmen turned to the rationality of science to help navigate their course between these competing alternatives.

especially Robert E. Schmaltz, "The Uncertainty of Predicting Results of An Interdiction Campaign," *Aerospace Historian* 17/4 (Winter 1970), 150-153.

Nonlinearity, Precision and the Cold War

"The word, which calls by the name of 'progress' its tendency towards a fatal precision, marches on from Taylorisation to Taylorisation."

Paul Valery, 1919[1]

The overriding lesson American airmen took from the war was that air power unleashed could indeed cause results all out of proportion to the effort expended, that air power was a positively nonlinear force. During the interwar period, airmen "had to overstate their case" about the decisiveness of air power because of a lack of evidence; "...we had to talk about air power in terms of promise and prophecy," Jimmy Doolittle told members of the Senate in 1945, "instead of in terms of demonstration and experience."[2] Toward the end of the war, General Ira Eaker advised airmen if anything to understate their claims "because of the overwhelming independent evidence arising from all sources."[3] The positive contributions of air power during the war led inexorably to the creation of an independent Air Force in 1947.[4]

Less clear, however, were the *ways* in which air power could best be applied to achieve national strategic objectives. Alternatives included close air support and battlefield interdiction in support of the land forces, discriminate precision strikes against vital components of an enemy's industrial and economic systems, and the less discriminate use of mass through sustained conventional attacks, incendiaries, or atomic

[1] Quoted in Nick Cohen, "The One Best Way: Frederick Winslow Taylor and the Enigma of Efficiency," *New Statesman* (13 Feb 1998).
[2] Robert F. Futrell, *Ideas, Concepts, Doctrine: A History of Basic Thinking in the United States Air Force, 1907-1964,* 2 volumes (Maxwell AFB, AL: Air University Press, 1971), 1, 75.
[3] General Ira C. Eaker cited in Col. John F. Turner, "Memorandum for Chief, Historical Division," 11 May 1945. AFHRA file no. 142.042-19.

bombs. Dedicated support of the Army held little appeal for the newly autonomous Air Force. While precision bombing better fit the Air Force's preference for strategic air power and American moral sensibilities, the escalating passion and brutality of the war, born out as fire raids on Dresden and Tokyo and the single-bomb destruction of Hiroshima and Nagasaki, had demonstrated the undeniable potential of indiscriminate mass.[5] The tension between these two undercurrents, the cultural and ideological preference for precision and the technological capability for annihilation, shaped the evolutionary course of American air power through the post war era.

The major developments of World War II, noted Walt Rostow, included not only the "revolutionary rise in the importance of air power," but also the "massive and systematic harnessing of science and technology to military purposes" that unleashed a technological "flow rather than the product of occasional inventiveness."[6] The same spirit that inspired the pursuit of "pickle-barrel" precision in the air forces, when combined with the mobilization of American industry, also provided effective technological means for mass destruction. The technological complexity that emerged from the combination of rapid innovation, increasing lethality, and mass production created what Thomas Hughes has called "a crisis in control" in the post-war Air Force.[7] In response, airmen and the civilian experts they hired turned to the efficiency of scientific methods developed during the war. Operations research and systems analysis, while quite effective in managing emergent technologies and solving tactical problems,

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[4] Herman S. Wolk, *Toward Independence: The Emergence of the United States Air Force, 1943-1947* (Washington, D.C.: Office of Air Force History, 1996).
[5] Mark Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam.* New York: The Free Press, 1989, 10.
[6] Walt Rostow, *The Diffusion of Power* (New York: Macmillan, 1972), 2.
[7] Thomas P. Hughes, *Rescuing Prometheus: Four Monumental Projects That Changed the Modern World* (New York: Vintage Books, 1998), 16.

were ill suited to the less mechanical elements of warfare, like military strategy and the political objectives it supported. Besides reinforcing the tendency to treat war as an engineering project, the managerial Taylorism of these methods also narrowed the scope of available air power alternatives, alternatives often required for the solution of military problems imposed by less "rational" opponents.[8] War's nonlinearity, as the nuclear stalemate of the Cold War and the conventional conflict in Korea would show, demanded an element of irrationality and a tolerance for the unpredictable as a complement to the rationality of science.

The Methods of World War II

American airmen in the Second World War (unlike in the First World War) applied great energy and effort to learning from their experience. This change in receptivity to real-time learning reflected not only the increasing importance of technological innovation, but also the need to show that the air forces deserved organizational independence. The technologically oriented and image-conscious Army Air Forces, reluctant to leave the collection and analysis of data to qualitatively minded historians, turned instead to the quantitative analytical approach of civilian technicians.[9] Operations research, which "attempted to apply systematic and especially quantitative analysis to the effort to secure optimal performance from weapons," originated with the

[8] Roger A. Beaumont, "The One Best Way to Oblivion?" *US Naval Institute Proceedings* 94 (December 1968), 37-41. On Taylorism and managerial efficiency, see especially Robert Kanigel, *The One Best Way: Frederick Winslow Taylor and the Enigma of Efficiency* (New York: Penguin Putnam, 1998).

[9] Conrad C. Crane, *Bombs, Cities, and Civilians: American Airpower Strategy in World War II* (Lawrence, KS: University Press of Kansas, 1993), 144-146; and Michael Sherry, *The Rise of American Air Power: The Creation of Armageddon* (New Haven, CT: Yale University Press, 1987), 229-230. On the Army Air Force's disappointing experience with its "Committee of Historians," see Gian P. Gentile, *How Effective is Strategic Bombing?Lessons Learned from World War II to Kosovo* (New York: New York University Press, 2004), 25-32.

British early in the war, but after the establishment of the first operations research section in VIII Bomber Command in October 1942, came to play a leading role in the American war effort.[10] By the end of the war there were over 400 analysts working in some seventeen different operational analysis sections throughout the Army Air Forces.[11]

One of the more important problems addressed by operations analysts during the war was the tactical accuracy of air weapons. By directive, operations analysis sections at the Air Force, Bombardment Division, Combat Wing, and Group level were to issue monthly bombing accuracy reports (although inadequate staffing and competing requirements meant less frequent reports in practice), with periodic reviews and special reports published as required by operational demands. Within the 8th Air Force, the "Bombing Accuracy Subsection" of the Operational Research Section not only analyzed bombing accuracy, but also translated statistics on accuracy directly into force requirements, submitting assessments of "the size of forces required to achieve particular results against different kinds of targets."[12] The improvements in bombing accuracy thanks to operations analysis were, according to historian I.B. Holley, "nothing short of

[10] See especially I.B. Holley, Jr., "The Evolution of Operations Research and Its Impact on the Military Establishment: The Air Force Experience," in Monte D. Wright and Lawrence J. Paszek, eds., *Science, Technology, and Warfare: The Proceedings of the Third Military History Symposium, United States Air Force Academy, 8-9 May 1969* (Washington, D.C.: Office of Air Force History, 1970), 89-109. See also Sir Solly Zuckerman, *Scientists and War: The Impact of Science on Military and Civil Affairs* (New York: Harper & Row, Publishers, 1966), 15-28; Russell F. Weigley, *The American Way of War: A History of United States Military Strategy and Policy* (New York: Macmillan, 1973), 407-409; Ian Gooderson, *Air Power at the Battlefront: Allied Close Air Support in Europe, 1943-45* (London: Frank Cass, 1998), 6-21; and Martin J. Collins, *Cold War Laboratory: RAND, the Air Force, and the American State* (Washington, D.C.: Smithsonian Institution Press, 2002), 112-113. For a primary account of the origins of operations research in the AAF, see John M. Harlan, "The Operational Research Section at the Eighth Air Force," 17 July 1944. AFHRA file no. 520.303-1.

[11] For a short summary of operations research and analysis work in the AAF during the war, see W. B. Leach, "Operations Analysis in World War II," 1948. AFHRA file no. 143.504. For a detailed list of AAF Operations Analysis Reports during the war, see "List of Operations Analysis Reports," 5 May 1946, Washington, D.C.: Headquarters, Army Air Forces. AFHRA file no. 143.504-23. A small sampling of the different OR sections in the AAF includes Arnold's Committee of Operations Analysts, the Operational Research Section of the USSTAF in Europe, and the Operations Analysis Section of the XXI Bomber Command in the Pacific. See also Futrell, *Ideas, Concepts, Doctrine,* 1, 142-143.

spectacular." In 1943, fifteen percent of the 8th Air Force's bombs were bombs falling within 1000 feet of the aiming point; by 1945, the number increased to sixty percent.[13]

Ascribing progress in bombing accuracy to operations analysis alone, however, is monocausal and reductionist, and somewhat akin to crediting the accountant for increased profits. Improvements were contingent on other factors independent of the work of operations analysts, like better bombsights, changing operational environments, and the growing size of the combined air forces. The neat statistical averages of the operations analysts that showed steadily decreasing error required substantial simplifications and were only as good as the available data. Monthly accuracy reports deliberately excluded attacks where bombers attacked targets of opportunity not specified in advance, where no group in the attacking force landed a bomb within 1000 feet of the aim point, or where inadequate photographic coverage prevented accurate appraisal of results.[14] One 8th Air Force study produced a linear mathematical equation using multiple regression analysis to predict "the radial errors of bombfall pattern centers" given values for antiaircraft defenses, bombing altitude, types of target, smoke or haze over the target, and degrees of drift of the bomb run. As the authors of the study acknowledged, however, their calculations failed to "account for errors resulting from such factors as difficulty in target recognition and other forms of personnel error which were poorly reported or for undescribed or inaccurately described tactical factors."[15] As Solly Zuckerman (who

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[12] Harlan, "The Operational Research Section of the Eighth Air Force," 6-7.
[13] Holley, "The Evolution of Operations Research," 91. See also Hughes, *Rescuing Prometheus*, 150; and Crane, *Bombs, Cities, and Civilians*, 64.
[14] "Bomber Command Instruction 15-2: Blank Forms and Reports, Strike Photos and Bombing Efficiency," Headquarters, VIII Bomber Command, 6 January 1944. AFHRA file no. 520.303-1.
[15] Thomas I. Edwards and Murray A. Geisler, "The Causes of Bombing Errors as Determined from Analysis of Eighth Air Force Combat Operations," Headquarters, Army Air Forces, 15 July 1947. AFHRA file no. 143.504-3. See especially 102-103 on the nonlinear nature of bombing errors and the simplifications required to linearize the relationship between cause and effect.

founded operational research in the Royal Air Force) later noted: "The less exact the information available for analysis, the less it is founded on experience, the more imprecise are its conclusions, however sophisticated and glamorous the mathematics with which the analysis is done."[16]

The post-war U.S. Strategic Bombing Survey (USSBS) similarly employed the statistical approach to measuring the effectiveness of air power.[17] The strategic bombing survey originated from within the Army Air Force staff in March 1944 and was authorized by presidential decree in November 1944. By June 1945, the USSBS organization had grown to over five hundred civilian economists and technical experts and three hundred military analysts. As a "scientific investigation of all the evidence," the USSBS focused on more easily quantifiable material and economic effects, rather than the political consequences of bombing.[18] According to Paul Nitze, an influential director of the Survey team, the purpose of the USSBS "was to measure precisely the physical effects and other effects as well, to put calipers on it... to put quantitative numbers on something that was considered immeasurable."[19] Employing the necessary personnel "made available through the patriotic offer of the Prudential Insurance Co.," the survey prepared two sets of approximately 1 million punch cards that recorded

[16] Zuckerman, *Scientists and War: The Impact of Science on Military and Civil Affairs* (New York: Harper & Row, 1966), 18.
[17] See David MacIsaac, *Strategic Bombing in World War II: The Story of the United States Strategic Bombing Survey* (New York: Garland Publishing, 1976) and Gian P. Gentile, *How Effective is Strategic Bombing? Lessons Learned from World War II to Kosovo* (New York: New York University Press, 2004). For the general conclusions of the USSBS in both Europe and the Pacific, see *The United States Strategic Bombing Surveys (European War) (Pacific War)*, reprint (Maxwell AFB, AL: Air University Press, 1987).
[18] Gian P. Gentile, "Shaping the Past Battlefield, "For the Future": The United States Strategic Bombing Survey's Evaluation of the American Air War Against Japan," *The Journal of Military History* 64/4 (October 2000), 1085-1086. See also Gentile, *How Effective is Strategic Bombing?*, 94. As one member of the survey team later reported, "We were all deeply moved by moral considerations, but we did not think that in the necessarily a-moral climate in which wartime decisions have to be made these would be effective." Quoted in Robert S. Jordan, *Norstad: Cold War NATO Supreme Commander* (New York: St. Martin's Press, Inc., 2000), 42.

statistical information on bombing missions and their targets.[20] Overly focused on the quantifiable at the expense of less tangible aspects of bombing, the USSBS nevertheless collected valuable data on the impacts of strategic air power that were transformed into numerous studies and reports – more than two hundred for the European portion of the Survey alone.[21]

The data the USSBS collected were intended to give clear insight into the causal relationship between American "precision" bombing and the defeat of Germany and Japan. Its conclusions, however, reflected instead the messy and indeterminate nature of the air war and the difficulties of linking cause and effect in war. "The interrelation of military, economic, and morale factors was complex," survey members concluded. "To a certain extent each reacted on the other."[22] Unable to precisely determine the true *effectiveness* of strategic bombing in subduing Germany and Japan, the USSBS, as air power historian David MacIsaac points out, settled instead for measures of *effect,* i.e. the immediate, direct, or physical consequences of bombing.[23] The need to compile the lessons of bombing in Europe quickly so that they could be applied in the Pacific also affected the survey's conclusions; survey teams working right on the heels of the

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[19] Quoted in Gentile, *How Effective is Strategic Bombing?*, 45.
[20] The United States Strategic Bombing Survey, *Statistical Appendix to Over-All Report* (European War), February 1947, vi. AFHRA file no. 137.301-1A.
[21] Gentile, *How Effective is Strategic Bombing?*, 55. As Conrad Crane notes, "A more effective analysis of nonquantifiable factors probably would not have changed formal doctrine, but it would have made leaders more aware of the actual effectiveness and the political implications of conventional bombing in urban areas. Such an analysis also might have suggested that different enemy economies and national characters or changing international relations could limit the effectiveness of future strategic air campaigns." Crane, *Bombs, Cities, and Civilians*, 147.
[22] *The United States Strategic Bombing Surveys (European War) (Pacific War)*, 96.
[23] MacIsaac, *Strategic Bombing in World War II*, 161. On the distinction between *effects* and *effectiveness*, see also Barry D. Watts and Thomas A. Keaney, *Part II: Effects and Effectiveness in Gulf War Air Power Survey, vol. II, Operations and Effects and Effectiveness* (Washington, DC: U.S. Government Printing Office, 1993), 71-103.

advancing armies, with the effects of bombing still emerging, could analyze only short term effects, and not long term strategic and political consequences.[24]

Among the many topics addressed by the survey's conclusion was bombing accuracy, which was somewhat noncommittally judged as ranging "from poor to excellent." High altitude precision daylight bombing in Europe had been less than perfectly efficient, as the summary report noted: "Of necessity, a far larger tonnage was carried than hit German installations." Throughout the entire war, only about twenty percent of bombs aimed at precision targets fell within 1000 feet of the aiming point. Accuracy, however, peaked in February 1945 when seventy percent of bombs fell within this area.[25] In the Pacific, before March 1945 only ten percent fell within 1000 feet; by bombing from lower altitudes after March 1945, bombing accuracy increased to thirty-five to forty percent for daylight attacks.[26] Despite these statistics, the survey downplayed the difficulties of hitting individual ships and Japanese factories in the Pacific theater, recommending a future doctrine of precision over urban or area bombing.[27]

Precision, not mass or area bombing, remained the preferred method for American air power after the war. "[T]he lessons of the bombardment of Germany are clear," wrote Vannevar Bush, the President's scientific advisor. "As matters then stood, and as between approximately equal antagonists, mass bombing was of dubious value,

[24] The survey teams, in fact, followed so closely to the front that some members became battle casualties, including four who were killed. *The United States Strategic Bombing Surveys (European War) (Pacific War)*, 4.
[25] *The United States Strategic Bombing Surveys (European War) (Pacific War)*, 13.
[26] *The United States Strategic Bombing Surveys (European War) (Pacific War)*, 84-85.
[27] Gentile, "Shaping the Past Battlefield," 1093-1094. Gentile's article stresses the politicized nature of the bombing survey in the Pacific.

and selective bombing was an essential element of coordinated attack."[28] For reasons of morality as well as tactical efficiency, increased precision was a consistent technological goal, in intent at least if not always in effect.[29]

The qualitative advantage the Army Air Forces held over the air forces of Germany and Japan by the end of the war, in part a function of the *quantitative* advantage the Americans eventually held in the air, was also due to the inherent technical aptitudes and bents of American airmen. Army Air Force recruits generally scored higher on the Army general-classification test and the mechanical-aptitude test than their brethren going to other branches.[30] This affinity for technology went beyond the inherent qualities of airmen; it was also carefully promoted and nurtured by Army Air Force leadership, in particular by "Hap" Arnold, the foremost air power gadgeteer. Arnold encouraged research and development and constant cooperation with civilian experts in science and industry to make technology an integral component of the air force.[31] His pragmatic approach to aviation technology was to energetically encourage research and development in peacetime, but to forego new experimental research once the war was on, focusing instead on further development and production of the best available designs.[32] To Arnold the technological pragmatist, precision air power was more than just a tenet of doctrine. It was a way to win the war and earn long-desired independence for the air

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[28] Vannevar Bush, *Modern Arms and Free Men: A Discussion of the Role of Science in Preserving Democracy* (Cambridge, MA: The M.I.T. Press, 1949), 87-96.
[29] See Crane, *Bombs, Cities, and Civilians*, 5.
[30] Crane, *Bombs, Cities, Civilians*, 48-49; Sherry, *The Rise of American Air Power*, 204-218; Ronald Schaffer, *Wings of Judgment: American Bombing in World War II* (New York: Oxford, 1985), 17-18.
[31] On Arnold's association with civilian engineers and scientists, see especially Dik Alan Daso, "Origins of Airpower: Hap Arnold's Command Years and Aviation Technology," *Aeorspace Power Journal* 11/3 (Fall 1997).
[32] See Henry H. Arnold, *Global Mission* (New York: Harper and Brothers, 1949), 178. See also Daso, "Hap Arnold's Command Years and Aviation Technology" and H.H. Arnold and Ira C. Eaker, *Winged Warfare* (New York: Harper & Brothers, 1941), 238-239.

forces. "Efficiency in winning the war is our goal, and, in bombing, efficiency and precision are synonymous. ...[O]ne mission per vital target instead of two or three, an actual saving in life and effort."[33] Under Arnold's wartime guidance, the Army Air Forces developed the technological stepping-stones to modern precision air power.

The first concern in the early development of guided air to ground munitions was in keeping aircrews out of harms way, allowing them to deliver their bombs without exposing themselves to the increasingly deadly barrage of flak over the target. Remotely controlled "standoff" weapons that accurately delivered from a distance would limit both friendly and enemy casualties, making aerial warfare more clean and "precise." Reaching back to his experience with the "Flying Bug" in WWI, Arnold turned to long-time associate Charles Kettering to develop a bomb that would glide one mile for each 1000 feet of altitude so that pilots could release their weapons well outside the range of enemy anti-aircraft guns.[34] The resulting GB-1, ready for deployment in 1943, was nothing more than a 12-foot wing, rudders, and elevator attached to a standard 2000-pound demolition bomb with a gyro mechanism similar to an autopilot to achieve a stabilized glide. A B-17 could carry only two of these somewhat awkward contraptions slung under its wings, although there was also a 500-pound version of the glide bomb

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[33] Arnold to all AAF commanders in combat zones, 10 June 1943. Quoted in Crane, *Bombs, Cities, and Civilians*, 63. As Arnold stated in his post-war report, "Indiscriminate widespread destruction of enemy industry is simply a waste of effort." General H.H. Arnold, "Second Report of the Commanding General of the Army Air Forces to the Secretary of War," 27 February 1945, in *The War Reports* (Philadelphia: J.B. Lippincott Co., 1947), 457.

[34] Crane, *Bombs, Cities, and Civilians*, 78-79 and 85-86. On the early development of the Kettering Bug, see Paul G. Gillespie, *Precision Guided Munitions: Constructing a Bomb More Potent Than the A-Bomb*, unpublished dissertation (Lehigh University: June 2002). On the development of "the aerial torpedo" during and immediately after WWI, see Thomas P. Hughes, *American Genesis: A Century of Technological Enthusiasm, 1870-1970* (New York: Viking, 1989), 126-135. On Arnold's interest in using the Kettering Bug in World War II, see H. H. Arnold, *Global Mission* (New York: Harper and Row, Publishers, 1947), 74-76 and 259-261; and Kenneth P. Werrell, *The Evolution of the Cruise Missile* (Maxwell AFB, AL: Air University Press, 1985), 12-17 and 26-30.

equipped with smaller wings that could be carried and released by a fighter aircraft as it simultaneously strafed its target. [35]

Notoriously imprecise, early glide bombs were more representative of Arnold's concern for saving the lives of American airmen than a step toward greater bombing precision.[36] In the first operational use of the GB-1 on May 1944 against the city of Cologne, none of the 116 weapons released hit the city. The attack did however encourage German gunners who mistook the glide bombs falling across the countryside for downed B-17's.[37] Given the weapon's inaccuracy, combat commanders like Spaatz, Eaker, and Doolittle were less enthusiastic than Arnold about the project; stabilized glide bombs therefore saw only limited operational use. Early work with glide bombs did, nevertheless, inspire more effective follow-on weapons. The GT-1, a glide torpedo developed for use in the Pacific achieved somewhat better results, but was employed on only a few occasions because of the limited range of the B-25 with the GT-1 attached and the weapon's mediocre results against smaller targets.[38]

Although Arnold's first priority was simple but inaccurate glide bombs that could be massed produced, he nevertheless allowed engineers to continue work on more complex guidance mechanisms to improve bombing accuracy.[39] Arnold was particularly interested in bombs or missiles that could home in on light, sound, metal, or could be

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[35] Sol E. Ernst, "Pilotless Aircraft Lecture," AAF School, Orlando, Florida, August 1945, 2-3. AFHRA file no. 248.21-2. See also Donald I. Blackwelder, *The Long Road to Desert Storm and Beyond: The Development of Precision Guided Bombs* (Maxwell AFB, AL: School of Advanced Airpower Studies, 1992), 9-11; and Craven and Cate, 6, 257-259.

[36] Dik Alan Daso, *Architects of American Air Supremacy: General Hap Arnold and Dr. Theodore von Kármán* (Maxwell AFB, AL: Air University Press, 1997), 84. As Arnold confessed, "the weapon is an area bomb." The average miss distance for the GB-1 was 3000-5000 feet in range and 700-1000 feet in azimuth when dropped from 15,000 feet above the ground. Blackwelder, *The Long Road to Desert Storm and Beyond*, 9.

[37] Crane, *Bombs, Cities, and Civilians*, 86. Craven and Cate, 6, 258.

[38] Craven and Cate, 6, 259.

[39] Craven and Cate, 6, 258.

guided using television.[40] As early as April 1942, engineers at Eglin were experimenting with various means to remotely control glide bombs, with radio control the most promising and the farthest along in development.[41] Two remotely controlled glide bombs, the GB-4, a radio controlled bomb using visual observation and the GB-8, with a television for the bombardier to guide the bomb to target, were tested in Europe during the summer of 1944, but the project was cancelled after unsatisfactory performance.[42]

A more successful guided bomb was the VB-1 or "AZON" (for "azimuth only"), a 1000-pound vertical bomb with an extended tail section housing a flare, a gyro assembly, and a rudder that allowed the bombardier looking down from the airplane to steer the bomb left or right.[43] First employed in Italy in April 1944 with disappointing results, at the end of May four B-17's dropped 24 AZON bombs that scored four direct hits, destroying a 70-foot section of the Avisio viaduct south of the Brenner Pass.[44] Despite generally poor results from the 3000 AZONs employed in Europe, AZONs were used more successfully in the China-Burma-India Theater, where the 7th Bombardment Group claimed to have destroyed seven bridges with 459 AZONs over a period of two months, achieving direct hits with 10-15% of the bombs.[45] The AAF also conducted

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[40] Arnold to von Karman, 27 December 1944. Murray Green collection. AFHRA MICFILM 43804.

[41] BG Benny Myers to Arnold, 18 April 1942. Murray Green collection. AFHRA MICFILM 43804. Myers reported that the precision version of the glide bomb would be ready for operational employment by the spring of 1943.

[42] Craven and Cate, 6, 259. The GB-4 was used against the submarine pens at LeHavre in 1944 with some success, attaining a 200 ft. circular error probable and an 80% reliability rate. In all, there were some 14 different versions of guided glide bombs. Blackwelder, *The Long Road to Desert Storm and Beyond*, 10-11.

[43] For a detailed study of azimuth guided bombs, see especially Grant D. Gordon, III, "A Case History of Azon, an Azimuth Guided Bomb," Air Command and Staff College, April 1987. AFHRA file no. K239.043-83. See also Blackwelder, The Long Road to Desert Storm and Beyond, 12-17.

[44] Gordon, "A Case History of Azon," 27-33. Crane, *Bombs, Cities, and Civilians*, 86-87.

[45] Craven and Cate, 6, 259-260; Gordon, "A Case History of Azon," 39-44. One report for January 1945 by the Operational Research Section of the Strategic Air Forces in the Pacific gave the average error for 99 AZON bombs released between ten and eleven thousand feet as 244 feet "in range" and 152 feet "in line." Operational Research Section, Air Command, South East Asia, "A Survey of the Operations of the

experiments with bombs that were both range and azimuth controlled ("RAZON") and autonomous bombs that would home in on their targets, but these bombs were not operationally employed during the war.[46] Other experimental developments in guided weapons during the war included: the Navy's series of radar homing glide bombs (the Pelican, Bat, and Moth); a television-guided bomb called Roc, whose guidance system left virtually no room for explosives; Felix, an autonomous target-seeking bomb; and even a bomb guided by an internally-carried pigeon trained to peck on a glass plate to center target images.[47]

By the end of the war, the guided weapons program had become the third largest research and development program in the AAF behind unguided bombs and jet propulsion.[48] Although still technologically immature, spotty success with early guided weapons hinted at their potential; Vannevar Bush noted that "the records indicat[ed] that one controlled bomb was worth one hundred ordinary ones."[49] The USSBS also took notice of the promising efficiencies of precision weapons: "The use of Azon guided bombs, which could have been made available at that time, would have greatly increased

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Strategic Air Force During January 1945," 15. AFHRA file no. 821.310-2. All total, the AAF dropped 1357 AZONs in Burma, destroying 41 bridges and damaging 12 more. The average error for these bombs was 131 feet in azimuth and 207 feet in range. Blackwelder, *The Long Road to Desert Storm and Beyond*, 14.

[46] Blackwelder, *The Long Road to Desert Storm and Beyond*, 14-15. Ernst, "Pilotless Aircraft Lecture," 2-3.

[47] Joseph C. Boyce, ed., *New Weapons for Air Warfare: Fire-Control Equipment, Proximity Fuzes, and Guided Missiles* (Boston: Little, Brown and Company, 1947), 225-273. See especially 245 on the complexity of guidance technology and the interdependent nature of component parts.

[48] Blackwelder, *The Long Road to Desert Storm and Beyond*, 11.

[49] Although successfully employed, Bush felt the weapons never caught on in Europe "largely because no real precision bombing was being done or attempted there except in support of troops, where rocket-equipped planes did very well indeed." Bush, *Modern Arms and Free Men*, 44. The National Defense Research Committee concluded that remote guidance improved standard bombing accuracy by a factor of thirty. Blackwelder, *The Long Road to Desert Storm and Beyond*, 13.

accuracy against targets of this type [bridges] and reduced force requirements to approximately one-sixth...."[50]

Despite their potential, the Army Air Forces did not actively pursue these predecessors to modern "smart bombs" immediately after the war. Factors other than tactical efficiency influenced the relative neglect of these technologies. The bombs were somewhat unpopular with pilots, especially in the European theater. This was because pilots were rated not on accuracy, but on numbers of sorties flown and tonnage dropped where Azon was at a distinct disadvantage. Aircrews also disliked having to continue their bomb run for an extra thirty seconds after bomb release in visual meteorological conditions.[51] And although they offered the capability for more efficient destruction of targets, the weapons were much more expensive than conventional bombs. Early guided bombs consequently lost favor amidst the growing obsession with rockets and missiles modeled after the German V-1 and V-2 and the irresistible power of atomic weapons.[52]

Another of Arnold the technological gadgeteer's pet schemes was Project APHRODITE, a plan to use several variants of unmanned bombers as guided weapons.[53] Arnold saw the project as a way to counter German V-weapons, while at the same time ridding the air forces of surplus B-17's and B-24's. General Spaatz, commander of the 8th Air Force, also saw benefit in freeing his strategic bombers from the tactical demands of the CROSSBOW campaign against V-1 and V-2 sites.[54] "Weary Willy" aircraft were

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[50] *The United States Strategic Bombing Surveys (European War) (Pacific War)*, 91.
[51] Boyce, *New Weapons for Air Warfare*, 261.
[52] Blackwelder, *The Long Road to Desert Storm and Beyond*, 15. See also Crane, *Bombs, Cities, and Civilians*, 87, and Gordon, "A Case History of Azon," 32-38.
[53] Werrell, *The Evolution of the Cruise Missile*, 32-35; Schaffer, *Wings of Judgment*, 85-86; and Crane, *Bombs, Cities, and Civilians*, 78-85.
[54] Arnold distinctly recalled the problem of surplus Liberty engines after WWI and the technological limitations these engines imposed on the air forces following WWI. Daso, *Architects of American Air Supremacy*, 84. See also Craven and Cate, 3, 727-728 and 6, 254-255; and Arnold, "Second Report," 456.

B-17's loaded with 20,000 pounds of explosives flown toward enemy lines, the pilot then bailing out over friendly territory, while the plane continued radio-controlled to its target using "double Azon" from an accompanying mother ship. "Willy Orphan" was the tactical version of the Weary Willy developed by the 9th Air Force, designed to use terminal guidance from ground controllers in close proximity to the intended target.

Like glide bombs, these remotely piloted bombers were an area, not precision weapon intended "as an irritant and possibly a means of breaking down the morale of the people of interior Germany."[55] Because each aircraft required 1500 man-hours of modification, they were a great burden for an already overloaded depot system and only a handful could be initially modified.[56] The 8th Air Force flew six Weary Willy missions between August 1944 and January 1945 involving eleven aircraft against German missile launching sites, the most accurate landing some 500 feet from its intended target.[57] Besides being inaccurate, the Wearys proved relatively easy to shoot down and were dangerous to both friendly ground personnel and aircrew – Lt. Joseph P. Kennedy was killed piloting the Navy's version of an APHRODITE aircraft.[58]

Arnold nonetheless persisted in his support for the project; the Army Air Force continued experimentation, adding primitive television guidance and a device to report readings from the aircraft altimeter by radio. At Yalta, the British Chief of the Air Staff Sir Charles Portal firmly opposed the project, vetoing the use of guided airplane bombs for fear of German retaliation in kind. In March 1945, American airmen reopened the question of the use of remotely controlled bombers. Although Churchill hesitantly

[55] Arnold to Spaatz, 23 November 1944. Murray Green collection. AFHRA MICFILM 43804.
[56] Spaatz to Arnold, 22 January 1945. Murray Green collection. AFHRA MICFILM 43804.
[57] Werrell, *The Evolution of the Cruise Missile*, 32; and Craven and Cate, 3, 727-728.
[58] Werrell, *The Evolution of the Cruise Missile*, 34.

consented, Truman, having assumed the presidency after the death of Roosevelt, quietly decided against their continued use. Even Arnold, having suffered a debilitating heart attack in January 1945, had by then soured on APHRODITE. "The project 'Willie Orphan' which seemed to offer such promise a short time ago has, because of many imponderables and because of inherent vulnerability, not justified the expenditure of time and critical materials which we have put into it."[59]

In a coevolutionary spiral of technological innovation, American air forces reacted to developments in the *Luftwaffe*, and then as the European war wound down, borrowed directly from it.[60] In April 1945, members of the newly formed Army Air Force Scientific Advisory Group, headed by Arnold's longtime scientific associate Dr. Theodore von Kármán, proceeded to Europe in the wake of the advancing Allied armies to mine the wealth of German research and development. The team, a small part of the larger Allied technological exploitation mission codenamed Operation LUSTY (*Luftwaffe* Secret Technology), traveled across Europe, visiting German laboratories, interviewing both German and Allied scientists and engineers, even witnessing test launches of the V-2.[61]

Besides collecting information on rockets, von Kármán's group sought out German research in radio-controlled bombs and guided anti-aircraft missiles. The German guided bomb project dated back to 1938; by September 1943, the *Luftwaffe* had

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[59] Arnold to Spaatz, undated. Murray Green collection. AFHRA MICFILM 43804.
[60] The late development of the cruise missile in the Army Air Forces gives one example of this technological coevolution. The AAF only took interest in the development of autonomously powered missiles after the discovery of the V-1 and V-2; even then, American cruise missiles were based on German examples. See Werrell, *The Evolution of the Cruise Missile.*
[61] Dik A. Daso, "Operation Lusty: The U.S. Army Air Forces' Exploitation of the Luftwaffe's Secret Aeronautical Technology, 1944-1945," *Aerospace Power Journal* (Spring 2002).

employed their equivalent of the VB-1, the Fritz X, against ships in the Mediterranean.[62] Although German guided weapons used both range and azimuth control, they were so unreliable that it was often difficult to tell whether bombs had been jammed or had simply malfunctioned.[63] The German program included both radio and wire-controlled versions of guided bombs, the latter designed to negate the effects of Allied jamming.[64] The *Luftwaffe* also developed a glide bomb, the Hs-293, which sank 400,000 tons of Allied shipping including a couple of destroyers during 1943 and 1944. An Allied bombing raid abruptly ended the German glide-bombing program in 1944, however, when it destroyed the entire squadron on the ground.[65] The Germans also had their own version of the War Weary bombers, using remotely controlled Ju-88's against naval targets.[66] The more than 100,000 tons of materials on German weapons programs the Scientific Advisory Group sent back to a London clearing house (including thousands of linear feet of experimental data) played an important part in the development of American guided weapons, if only to confirm the path of American technological progress.[67]

In addition to promoting the technological innovation required for better precision bombing during the war, Hap Arnold also shaped the Army Air Force's attitudes toward future technological development.[68] With the outcome of the air war still undecided,

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[62] Blackwelder, *The Long Road to Desert Storm and Beyond*, 5-7. On German guided weapons programs, see also Gillespie, *Precision Guided Munitions*, 57-59.
[63] Bush, *Modern Arms and Free Men*, 43-45.
[64] Blackwelder, 6-8.
[65] Boyce, *New Weapons for Air Warfare*, 264.
[66] The British, in their opposition to APHRODITE, argued that the Germans could improve their own remotely piloted bombs using captured Allied technologies. Crane, *Bombs, Cities, and Civilians*, 84.
[67] Daso, "Operation Lusty."
[68] John F. Huston, "The Wartime Leadership of 'Hap' Arnold," in Alfred F. Hurley and Robert C. Ehrhart, eds., *Air Power and Warfare: The Proceedings of the 8th Military History Symposium, United States Air Force Academy, 18-20 October 1978* (Washington, D.C.: Office of Air Force History, 1979), 181. See also

Arnold focused on immediate technological applications that could produce effects "within the next 6 months to two years."[69] After Normandy (the successful conclusion of the war now only a matter of time), Arnold shifted his vision farther into the future. Technology, which played such an important role in the war against Germany and Japan, would play an even greater part in any future war against the Soviet Union where a qualitative edge would be needed to overcome a quantitative disadvantage.[70]

Arnold's vision included an alliance between the military and civilian scientific and industrial community that would bind together the various agencies responsible for the development and production of future aviation technology under the protective wings of an independent Air Force.[71] Arnold disagreed with Vannevar Bush who wanted to leave the creation of new weapons to an independent civilian agency; instead, Arnold wanted the future Air Force to assume responsibility for its own research, development, and procurement of new technologies.[72] Given the speed and uncertainty of innovation in warfare, Arnold feared that the next "push-button war" would involve sudden and devastating attack where there would little time to pursue new weapons. Military technological innovation, unlike in previous post war periods, would need to be a

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Thomas M. Coffey, *Hap: The Story of the U.S. Air Force and the Man Who Built It* (New York: Viking, 1982), 358-375.

[69] Henry H. Arnold and Ira C. Eaker, *Winged Warfare* (New York: Harper and Brothers, Publishers, 1941), 238-239. See also Daso, *Architects of American Air Supremacy*, 188.

[70] "National safety," wrote Arnold in his final wartime report, "would be endangered by an Air Force whose doctrines and techniques are tied solely to the equipment and processes of the moment. Present equipment is but a step in progress, and any Air Force which does not keep its doctrines ahead of its equipment, and its vision far into the future, can only delude the nation into a false sense of security...." Quoted in Futrell, *Ideas, Concepts, Doctrines*, 1, 180.

[71] Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore: Johns Hopkins University Press, 2002), 19.

[72] Bush was especially critical of the Arnold's pet projects like APHRODITE, which he described as an "illustration of what can happen when military requirements are written by enthusiasts with little grasp." Bush, *Modern Arms and Free Men*, 76. See also Daso, *Architects of American Air Supremacy*, 86-88; and Theodore von Kármán and Lee Edson, *The Wind and Beyond: Theodore von Kármán, Pioneer in Aviation and Pathfinder in Space* (Boston: Little, Brown and Company, 1967), 271-272.

continuous, ongoing project. Since the required technological expertise lay outside the military, Arnold worked to build a network of connections to the sources of innovation in the "long-hair" scientific community to give the Air Force a stronger hand in writing the technological future of air power. "The next Air Force," mused Arnold, "is going to be built around scientists – around mechanically minded fellows."[73]

One of Arnold's most important acts in the institutionalization of science and technology in the future Air Force was the founding of the Scientific Advisory Group under von Kármán in late 1944.[74] At a secretive meeting at LaGuardia Airport in September 1944, Arnold told von Kármán that "We have won this war, and I am no longer interested in it. I do not think we should spend time debating whether we obtained the victory by sheer power or by some qualitative superiority. Only one thing should concern us. What is the future of airpower and aerial warfare? What is the bearing of the new inventions, such as jet propulsion, rockets, radar, and the other electronic devices?" Arnold, according to von Kármán, was "already casting his sights far beyond the war, and realizing, as he always had, that the technical genius which could help find answers for him was not cooped up in military or civilian bureaucracy but was to be found in universities and in the people at large."[75] Besides exploiting existing German technologies, Arnold charged von Kármán and his group of civilian scientific experts with assessing and predicting the future of military aeronautics by divorcing themselves

[73] Von Kármán, *The Wind and Beyond*, 271.
[74] See especially Michael H. Gorn, ed., *Prophecy Fulfilled: "Toward New Horizons" and Its Legacy* (Washington, D.C.: Air Force History and Museums Program, 1994), 1-16. Both the SAG's initial report in August 1945,*Where We Stand*, and their final report of December 1945, *Toward New Horizons* are both included in this volume. See also Daso, *Architects of American Air Supremacy*, 194; and Arnold, *Global Mission*, 532-533.
[75] Von Kármán, *The Wind and Beyond*, 267-272.

"from the present war in order to investigate all the possibilities and desirabilities for postwar and future war's development as respects the AAF."[76]

The Scientific Advisory Group's initial report in August 1945, *Where We Stand*, highlighted the universal role of radar as a means for achieving precision in navigation and targeting.[77] *Toward New Horizons*, von Kármán's final 13-volume report delivered to Arnold in December 1945, stressed the importance of "organized science" in the future development not only of radar, but also in designing more effective weapons. Despite its overall technological optimism, the report was decidedly pessimistic about the prospects of precision bombing given the detrimental influences of weather, enemy interference, and the "unalterable reaction time of the human operator."[78] "Hence, in most cases pin-point bombing has to be replaced by area bombing," von Kármán's introductory volume *Science: the Key to Air Supremacy* observed, making it "necessary to revise bombing equipment in the light of future methods of strategy, including the use of atomic bombs."[79] The study also recognized the growing technological complexity involved with the development of "smart" weaponry and the need to consider the synergistic effects of technological combinations. "Perhaps the major problem in the design of the pilotless bomber is the coordination of all elements.... The tag characteristics of the intelligence device and of the autopilot and associated servomechanisms are perhaps the

[76] Arnold to von Kármán, 7 November 1944, in Gorn, ed., *Prophecy Fulfilled*, 87.
[77] *Where We Stand*, in Gorn, ed., *Prophecy Fulfilled*, 74-80; Daso, *Architects of American Air Supremacy*, 133-145.
[78] *Beyond New Horizons* in Gorn, ed., *Prophecy Fulfilled*, 138-142.
[79] *Beyond New Horizons* in Gorn, ed., *Prophecy Fulfilled*, 138; Daso, *Architects of American Air Supremacy*, 375. Bush reflected the same pessimism in his analysis of the future of guided bombs. "...in the use of conventional bombs against land targets, from very high altitudes, guided and homing bombs, while they will aid, will not be likely to overcome the disabilities of flying very high." Bush, *Modern Arms and Free Men*, 55.

most important factors, but the stability and accuracy are dependent on many other factors...."[80]

Although institutionalized as the Scientific Advisory Board by Arnold's successor General Carl Spaatz in June 1946, the distractions of rapid demobilization, declining budgets, and the need to focus on service unification and Air Force independence prevented the full realization of many of the Scientific Advisory Group's prescient technological recommendations.[81] Nevertheless, *Beyond New Horizons'* strengthened the view that modern science held solutions to the problems of aerial warfare. Arnold and von Kármán were well aware of the unavoidably subjective human element and the difficulties involved in the transition from the technological device to the complex, interdependent system.[82] But much as Laplace had simplified and overextended Newton's theories of mechanics in the 18th century, Air Force "technicians" would later overextend the Scientific Advisory Group's mechanical mindset to broader problems of warfare, like the development of aerial strategy in an era of atomic weapons, at the expense of less technically quantifiable considerations, e.g. the value components these problems could present.[83]

One of the most significant organizations in the expansion of the scientific mindset to the realms of strategy was the RAND Corporation, established in 1946 as one

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[80] *Beyond New Horizons* in Gorn, ed., *Prophecy Fulfilled*, 140.
[81] Alan Gropman, "Air Force Planning and the Technology Development Process in the Post-World War II Air Force – the First Decade (1945-1955)," in Harry R. Borowski, ed., *Military Planning in the Twentieth Century: The Proceedings of the Eleventh Military History Symposium, 10-12 October 1984* (Washington, D.C.: Office of Air Force History, 1986), 165-169. The Air Force rapidly declined from a peak strength of 2,411,294 in March 1944 to less than 900,000 by the end of December 1945 and about 300,000 in May of 1947. Herman S. Wolk, *Planning and Organizing the Post-War Air Force, 1943-1947* (Washington, D.C.: Office of Air Force History, 1984), 117. On the continuing impacts of the SAG and the Scientific Advisory Board during the Cold War, see Thomas A. Sturm, *The USAF Scientific Advisory Board: Its First Twenty Years, 1944-1964* (Washington, D.C.: Office of Air Force History, 1986).
[82] See Daso, *Architects of American Air Supremacy*, 186-187.
[83] Hughes, *Rescuing Prometheus*, 193.

of Arnold's last official acts.[84] Recognizing the increasing complexity of aviation technology, Arnold diverted $10 million dollars of Army Air Force research and development money in January 1946 to Edward L. Bowles, an MIT professor and scientific advisor in the Pentagon, to set up a research facility with the Douglas Aircraft Company dedicated solely to the future technological problems of the Air Force.[85] In May 1948, Project RAND split from Douglas to become the first non-profit research and development agency in the United States. By 1950, the RAND Corporation had blossomed into an organization of over 800 people.[86]

RAND's stated objective was to offer a "program of study and research on the broad subject of intercontinental warfare." Much like operations research during the war, the RAND concept reflected the shifting view of air warfare as a legitimate domain for scientific research. RAND, however, was more than just a simple extension of operations research; it was an integral part of the broader post-war push to build connections between science and the Air Force, to fabricate a science of air warfare.[87] Unlike operations research, which focused on the analysis of historical data, RAND specialized in forecasting and analyzing alternative futures. RAND's early focus was on more narrow technological problems of propulsion and guidance and the development of an effective intercontinental ballistic missile. With the incorporation of a nucleus of social

[84] On the formation of RAND and its impact on Air Force culture, see especially Collins, *Cold War Laboratory*.
[85] The founding of RAND was intended to answer the Navy's establishment of the Office of Naval Research in the ongoing political battle for defense resources and to counterbalance Vannevar Bush's approach to military research at the Office of Scientific Research and Development. There were also personal motivations involved in setting up RAND. Arnold was a close friend of Bowles and had family ties to Donald Douglas. Daso, *Architects of American Air Supremacy*, 156.
[86] Gropman, "Air Force Planning," 169; Daso, *Architects of American Air Supremacy*, 156.
[87] Collins, *Cold War Laboratory*, 110.

science scholars in 1947, however, RAND expanded its pursuits to broader aspects of politics and strategy.[88]

Among the many research projects at RAND was the development of "systems analysis" which relied on massive calculation and comparison of multiple variables to model and solve the complex problems of modern war in a cost-effective manner.[89] RAND systems analysts, in their pursuit of a science of air warfare, followed a progression from the quantitative analysis of technological systems, through comparative calculations of "military worth," to a "Strategic Bombing Systems Analysis" that extended the quantified engineering approach to the more organic, and therefore less amenable, systems of war.[90] Through the work of social scientists like John Williams, Bernard Brodie, and Albert Wohlstetter, RAND's influence spread from the Air Force across the entire American defense community, conditioning two generations of defense analysts with the scientifically oriented approach.[91] Although intended to reduce air warfare to a manageable engineering problem, the science and efficiency of the analytical Taylorism encouraged first by Arnold and later by RAND overrode an appreciation for

[88] Gropman, "Air Force Planning," 171. Collins, 138-139.
[89] Collins, *Cold War Laboratory*, xiii. Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: The Massachusetts Institute of Technology Press, 1996), 115-117. Gropman, "Air Force Planning," 171-172. For an early example of Air Force systems analysis that compares the cost-effectiveness of the B-47, B-50, and B-36 bombers, deriving quantitative estimates for "cost per ton of bombs on target" given varying levels of bombing accuracy, see Standards Evaluation Branch, DCS Comptroller, "Relationship of Costs of Strategic Bombing to Attrition and Bombing Accuracy," 22 December 1949. AFHRA file no. 146.003-133.
[90] Perhaps the best example of RAND's quantified approach to military systems is Warren Weaver's work on a "General Theory of War" that attempted to define a mathematical description of air warfare based on general criteria, functions, and variables. See Collins, *Cold War Laboratory*, 116-119.
[91] Weigley, *The American Way of War*, 409-410, 425-426. Collins, *in toto*. Bernard Brodie considered RAND's system analysis "far superior to anyone's simple, intuitive judgment." Bernard Brodie, *War and Politics* (New York: Macmillan Publishing Co., Inc., 1973), 453-464.

the inescapable irregularity of war, irregularity that would resurface during the Cold War in both Korea and Vietnam.[92]

The Precision of Nuclear Weapons

Dropped by a B-29 using a Norden bombsight in visual conditions, the first atomic bomb missed its aiming point by 800 feet. The massive effects of the bomb, however, made this imprecision irrelevant.[93] The USSBS estimated that the fission bomb dropped on Hiroshima was the equivalent of 220 B-29's carrying 1,200 tons of incendiary bombs, 400 tons of high-explosive bombs, and 500 tons of anti-personnel fragmentation bombs, with an accuracy equal to that achieved in the last three months of the war.[94] As Kármán reported to Arnold, "...the tremendous zone of damage of the atomic bomb diminishes the required precision. Hence, the difficult control problem is made easier."[95] Technological development, the primary source of improved bombing accuracy, now threatened to eclipse it.

A "revolutionary" weapon is one that provides positively disproportionate effects when introduced on the battlefield. After Hiroshima and Nagasaki, American airmen saw the emergence of atomic weapons not as a revolution in and of itself, but as a natural extension of the ongoing transformation of war brought about by the introduction of air power. Atomic weapons in essence magnified the effects of air power, finally

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[92] Colin Gray, *Weapons for Strategic Effect: How Important is Technology?*, Air University Occasional Paper No. 21 (Maxwell AFB, AL: Air University Press, January 2001), 10.
[93] Gillespie, *Precision Guided Munitions*, 61-62.
[94] *The United States Strategic Bombing Surveys (European War) (Pacific War)*, 102-103.
[95] Theodore von Kármán, "Where We Stand," 22 August 1945 in Daso, *Architects of American Air Supremacy*, 240.

vindicating the revolutionary visions of Gulio Douhet.[96] Rather than displacing established American conceptions of air power, the destructive potential of the atomic bomb was bonded on to existing ideas for an all-out offensive to destroy the industrial fabric of an enemy society.[97] As the influential members of the Spaatz Board, convened in 1945 to evaluate the impact of nuclear weapons on air warfare, concluded, "The atomic bomb has not altered our basic concept of the strategic air offensive but has given us an additional weapon."[98] After 1945, the Air Force came to associate air power with not just bombs on target, but nuclear bombs on target.[99] By 1954, Air Force *Basic Doctrine* boldly predicted "The use of weapons of mass destruction in air operations against the heartland will result in effects out of all proportion to the effort expended and the costs involved. Therefore, lack of control of the air must not, in itself, deter commitment of the entire striking force in order to achieve results calculated to be decisive."[100] Relying on the apparent efficiency and cost effectiveness of nuclear weapons to counter Soviet conventional superiority, airmen adopted "the absolute weapon" as a fundamental element in the postwar conception of American air power.

Despite the unifying experience of World War II and the demonstrated importance of tactical air power, American air forces "fractionated" into their tactical and

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[96] Karl P. Mueller, "Strategic Airpower and Nuclear Strategy: New Theory for a Not-Quite-So-New Apocalypse," in Phillip S. Meilinger, ed, *Paths of Heaven: The Evolution of Airpower Theory* (Maxwell AFB, AL: Air University Press, 1997), 281-282. See also McMullen, *The United States Strategic Bombing Survey and Air Force Doctrine*, 44-45.

[97] See Bernard Brodie, *Strategy in the Missile Age* (Princeton, NJ: Princeton University Press, 1965), 152-154.

[98] The Spaatz Board consisted of Generals Spaatz, Vandenburg, and Norstad John T. Greenwood, "The Atomic Bomb – Early Air Force Thinking," *Aerospace Historian* 34 (Fall 1987), 158-162. See also Carl Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the U.S. Air Force* (New Brunswick, NJ: Transaction Publishers, 1994), 135-138; and Jordan, *Norstad*, 44.

[99] See especially Robert F. Futrell, "The Influence of the Air Power Concept on Air Force Planning, 1945-1962," in Harry R. Borowski, ed. *Military Planning in the Twentieth Century: The Proceedings of the Eleventh Military History Symposium, 10-12 October 1984.* Washington, D.C.: Office of Air Force History, 1986, 253-274.

strategic functional specialties after the war with increasingly greater emphasis on the mission of strategic nuclear bombardment.[101] In January 1946, General Spaatz, Arnold's successor as Chief of Staff, reorganized the combat elements of the Army Air Forces into a Strategic Air Command (SAC), Tactical Air Command (TAC), and Air Defense Command (ADC). First priority in an era of demobilization and scarce resources went to the "the backbone" of the Air Force, the bombers and protective fighters of SAC. TAC and ADC were subsequently combined into a Continental Air Command in 1948 by Spaatz' successor, General Hoyt Vandenburg.[102] Thus with the growing ascendancy of nuclear weapons came the bureaucratic and cultural predominance of SAC within the American air power system. The reopening of military purse strings in 1950 with NSC-68 and the invasion of South Korea furthered this trend since the greater part of the massive expansion of the Air Force throughout the 1950's occurred in the strategic, and not in the tactical, air forces. NSC 162/2 and the Eisenhower administration's "New Look" strategy, which sought military efficiency through near exclusive reliance on the disproportionate effects of nuclear weapons, brought SAC to the height of its power within the American defense establishment.[103] The heavy burden of defense spending on already fiscally strained NATO partners in Europe further reinforced the inclination toward dependence on American nuclear air power rather than conventional air or ground forces.[104] Part of the larger whole of national security strategy, the end result of greater political and strategic emphasis on nuclear warfare was that tactical aircraft were only

[100] AFM 1-2, *United States Air Force Basic Doctrine*, 1 April 1954, 14. AFHRA file no. K168.03-2346.
[101] See especially Builder, *The Icarus Syndrome*, 35 ff.
[102] Futrell, "The Influence of the Air Power Concept on Air Power Planning," 257. Builder, *The Icarus Syndrome*, 139-141. Futrell, *Ideas, Concepts, Doctrine*, 108 and 239-245.
[103] Futrell, "The Influence of the Air Power Concept on Air Power Planning," 262-267.
[104] Futrell, *Ideas, Concepts, Doctrine*, 220.

tolerated within the American air forces to the extent that they could contribute to the overarching strategic nuclear mission.[105]

The rise of SAC was not just the simple result of larger trends in national security, but was also the product of individual agency. Like Mitchell and Arnold in the early years of American air power, Curtis LeMay played an influential personal role in promoting strategic air forces during air power's middle years.[106] Trained as a navigator, the operationally oriented LeMay was uninterested in theory or strategy and learned little while at the Air Corps tactical school. Suspicious of individual genius, LeMay preferred "a group of average individuals who were highly motivated."[107] A pragmatist like Arnold, LeMay earned his reputation as an innovator during World War II. Although some of LeMay's innovations furthered the doctrine of precision (like the use of non-evasive bomber formations and the employment of "Pathfinders" to improve bombing accuracy), LeMay was best known for his innovations in the methods of mass destruction.[108] In Europe as commander of the 305th Bombardment Group of the Eighth AF, LeMay led the way in the development of blind bombing and was an enthusiastic supporter of the experimental development of incendiaries. In January 1945, LeMay replaced Haywood Hansell as Commander of the 20th AF in the Pacific and, relatively unrestrained thanks to loose command relationships and General Arnold's debilitating

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[105] MacIsaac, "The Evolution of Air Power Since 1945," 18. See also Futrell, *Ideas, Concepts, Doctrine*, 310-311.

[106] For a popular biography of LeMay, see Thomas M. Coffey, *Iron Eagle: The Turbulent Life of General Curtis LeMay* (New York: Crown, 1986). For a short summary of LeMay's career and a critique of Coffey's biography, see Phillip S. Meilinger, *Airmen and Air Theory: A Review of the Sources* (Maxwell AFB, AL: Air University Press, 2001), 59-63. See also LeMay and Kantor, *Mission with LeMay* and Victor Davis Hanson, "The Right Man," *Military History Quarterly* (Fall 1996), 56-65.

[107] Quoted in Crane, *Bombs, Cities, and Civilians*, 125.

[108] One airman from the 8th Air Force during World War II called LeMay's formation tactics in "a conceptual breakthrough" that "transformed the accuracy of our bombing runs." Robert Morgan and Ron Powers, *The Man Who Flew the Memphis Belle* (New York: Penguin Books, 2002), 130-131.

heart attack, stripped his B-29's of guns and loaded them with incendiaries with devastating results for Japanese cities.[109]

Although LeMay himself admitted that he "didn't know much about research and development," the Spaatz board assigned LeMay to the newly created position of Deputy Chief of Air Staff for Research and Development. Not surprisingly given LeMay's preference for the present over the future, the technological offshoots nurtured by Arnold and von Kármán withered under LeMay's tenure. LeMay's vision, centered on the manned bomber, came to replace Arnold's vision of a manless Air Force fighting a clean, push-button war. Air Force research and development remained under-funded until, as von Kármán noted, perceptions of technological inferiority in the Korean War "tore into military complacency and resulted in a more receptive attitude to research."[110]

In 1947 and 1948, LeMay as commander of United States Air Forces in Europe was behind the success of the Berlin Airlift, known to many American airmen as "LeMay's Grain and Feed Company." On 19 October 1948, LeMay began his long tenure as Commander of SAC where, as General O.P. Weyland later related, "[LeMay] discovered to his pleasant surprise... that he had most of the chips. [But] he wasn't satisfied with having most of them; he wanted all of them."[111] LeMay, committed to winning any future war against the Soviet Union quickly and decisively, was one of the first and loudest voices to call for a doctrine of preemptive "first strike."[112] During his controversial reign as commander of SAC and later as Chief of Staff of the Air Force, LeMay had an important hand in pushing American air power away from conventional

[109] Crane, *Bombs, Cities, and Civilians*, 123-124.
[110] Von Kármán, *The Wind and Beyond*, 304. See also Daso, *Architects of American Air Supremacy*, 159-160; and Gropman, "Air Force Planning," 187-193.
[111] U.S. Air Force Oral History Interview, Gen. O.P. Weyland, 100.

precision and discrimination toward massive and decisive nuclear destruction. "From the practical standpoint of the soldiers out in the field it doesn't make any difference how you slay an enemy," wrote LeMay. "Everybody worries about their own losses. ... If we accomplished the job in any given battle without exterminating too many of our own folks, we considered that we'd had a pretty good day."[113]

Possible alternatives for American air power during the height of the Cold War were also shaped by technological limitations and uncertainty about future technological developments. Manned bombers continued to hold the predominant place in American air power theory and doctrine through the early 1950's since early ballistic missiles were inherently inaccurate and incapable of carrying large fission devices.[114] Missiles were also difficult to quickly retarget and impossible to recall once launched. Early missile development focused primarily on air-breathing cruise missiles, like the Snark and Navaho, which were in essence evolved, unmanned forms of the strategic bomber and therefore, as Carl Builder contends, more comforting to airmen and their biases for the airplane.[115] By the late 1950's, the growing potential of missiles as nuclear delivery vehicles, the emergence of smaller fusion bombs more compatible not only with ballistic missiles, but also with tactical aircraft and field artillery, and the development of inertial navigation devices, challenged the systemic bias for manned bombers.[116] Nevertheless,

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[112] Jordan, *Norstad*, 44.
[113] LeMay and Kantor, *Mission with LeMay*, 382.
[114] Robert F. Perry, "The Interaction of Technology and Doctrine in the USAF," in Alfred F. Hurley and Robert C. Ehrhart, eds., *Air Power and Warfare: The Proceedings of the 8th Military History Symposium, United States Air Force Academy, 18-20 October 1978* (Washington, D.C.: Office of Air Force History, 1979), 388. See also Mueller, "Strategic Airpower and Nuclear Strategy," 282-284.
[115] Builder, *The Icarus Syndrome*, 32-34 and 165-178. For an early passionate defense of manned aircraft that argues that a reliance on unmanned missiles "underplays the complexity of the air war and treats it as a cut-and-dried kind of science... that can be calculated and forecast with precision," see Dale O. Smith, "Pilots or Robots?" *Air Force Magazine* (November 1953). AFHRA file no. K168.11-1.
[116] Rostow, *The Diffusion of Power*, 68-69.

early versions of the Atlas and Titan Intercontinental Ballistic Missiles (ICBMs) and the Polaris Submarine Launched Ballistic Missile (SLBM) were still area weapons – accuracy was a matter of putting a nuclear package in the right zip code rather than in the correct mailbox. Not until the Minuteman series of ballistic missiles did the United States acquire a true precision ballistic missile capability.[117]

Since airmen equated air power with strategic striking power, developing survivable delivery platforms for nuclear weapons took priority over the development of accurate, guided conventional weapons.[118] The relative neglect of missiles and the emphasis on aircraft survivability during the early Cold War slowed technological progress in precision weapons guidance. Guided weapons did not follow a neat linear progression from the innovations of World War II and Korea; it was not until the LINEBACKER operations at the end of the Vietnam War that technological development in precision weapons emerged from its markedly flat course.

Despite the emphasis on the massive effects of nuclear weapons at the expense of accuracy, an undercurrent of precision and the associated idea of discrimination in bombing still managed to survive in American air power thinking. There were several forces that pushed for greater bombing precision and the superior discrimination of conventional weapons. From the end of World War II through the Korean War, the military could not afford to squander its atomic bombs as the few weapons in the inventory were needed for the continuing deterrence of conventional Soviet forces in

[117] For a more extensive discussion of the development of ballistic missile technology, see Futrell, *Ideas, Concepts, Doctrine*, 477-568.
[118] Gillespie, *Precision Guided Weapons*, 103-104.

Europe.[119] General Spaatz, recognizing the scarcity and cost of atomic weapons, advocated the continued development of conventional precision bombing to supplement atomic capabilities during his tenure as Chief of Staff.[120]

Organizational independence and the life and death nature of Cold War competition with the Soviet Union somewhat inured the Air Force to outside influences (including traditional American moral sensibilities). The postwar Air Force, however, was not entirely immune to criticism from the Navy and others that it was ignoring its conventional roles to develop expensive aircraft like the giant B-36 bomber for the delivery of nuclear weapons.[121] Even after Korea opened the floodgates of military spending and nuclear weapons became overly abundant, precisely guided nuclear weapons better fit with the meticulous analysis of overly engineered American war plans than did less accurate area weapons. Toward the end of the Eisenhower administration, new counterforce targeting schemes that put a premium on the destruction of hardened silos and command bunkers, the development of tactical nuclear weapons, and new doctrinal calls for the application of "precisely measured power directly against specific elements of hostile strength" encouraged greater mechanical precision in the delivery of nuclear weapons.[122]

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[119] The American nuclear stockpile consisted of 2 warheads in 1945, 9 in 1946, 13 in 1947, 50 in 1948, and 250 in 1949. By 1950, the number of nuclear weapons was 299 and by mid-1951, it reached 447 weapons. Futrell, "The Influence of the Air Power Concept on Air Power Planning," 257-262. Through 1948, none of the weapons was actually assembled and it took 39 men two days to assemble a Mark III "Fat Man" bomb. Furthermore, there were only about 30 "Silver Plate" B-29's modified to carry atomic bombs and all of these were located in the 509th Bomb Group in Roswell, New Mexico. David Alan Rosenberg, "The Origins of Overkill: Nuclear Weapons and American Strategy," *International Security* 7 (Spring 1983), 14-15.
[120] Mets, *Master of Airpower*, 314-315.
[121] Weigley, *The American Way of War*, 372-377.
[122] AFM 1-2, *United States Air Force Basic Doctrine*, 1 December 1959, 14. AFHRA file no. K168.03-2346.

Nuclear targeting debates between "counterforce" (military and industrial targets) and "countervalue" (cities and populations) schemes mirrored tensions between the desire for precision and discrimination and the capability for annihilation in conventional air power.[123] Within the Air Force, this debate took the form of "horizontal" versus "vertical" targeting. Vertical targeting, preferred by the Air Staff in Washington, limited strikes to key industrial nodes; horizontal targeting strategies, the choice of LeMay and SAC, stressed the "bonus effects" of mass attacks on cities where "a heterogeneous assortment of targets is wiped out and the effects spread laterally into the nation's life."[124] Those who preferred counterforce and vertical options, like the analysts at RAND, argued that the effects of attacks on military and industrial targets could be better predicted and more easily measured than the psychological effects on populations.[125] These military scientists sought analytical precision in their choice of nuclear targets. The nonlinear logic of massive retaliation and deterrence, however, introduced new and decidedly unscientific methods of calculation, making the effects of air power even less tangible and ever more contingent on unquantifiable, subjective factors.[126] Paradoxical ideas like the military value of the nonuse of weapons only clouded the causal clarity sought by nuclear strategists.[127] Or as one Air University lecturer so concisely demonstrated the

[123] Weigley, *The American Way of War*, 439-443.
[124] AFM 1-8, *Strategic Air Operations*, 1 May 1954, 4-6. AFHRA file no. 168.7045-122. See also Crane, *American Air Power Strategy in Korea*, 17-18; and Futrell, *Ideas, Concepts, Doctrine*, 218-219.
[125] Futrell, *Ideas, Concepts, Doctrines*, 436.
[126] On the evolution of strategic doctrines and its impact on air power technology, see especially Melvin Kranzberg, "Science-Technology and Warfare: Action, Reaction, and Interaction in the Post-World War II Era," in Monte D. Wright and Lawrence J. Paszek, eds. *Science, Technology, and Warfare: The Proceedings of the Third Military History Symposium, United States Air Force Academy, 8-9 May 1969* (Washington, D.C.: Office of Air Force History, 1970), 138-143.
[127] Weigley, *The American Way of War*, 366. Bernard Brodie, *The Absolute Weapon: Atomic Power and World Order* (New York: Harcourt, Brace, and Company, 1946), 76.

tension between discrimination and annihilation, "The SAC attacks when they come will be precision attacks with an area weapon."[128]

Like earlier plans for conventional air warfare, plans for strategic nuclear attacks reflected the American "scientific" approach to warfare that focused on quantifiable elements at the expense of less tangible qualitative aspects.[129] One of the first plans in 1948 for strategic nuclear attack labeled HALFMOON spoke with quantitative certainty of striking twenty urban targets with fifty atomic bombs to cause the "immediate paralysis of at least 50 percent of Soviet industry."[130] This modern version of war by algebra, despite its objective outward appearance, failed to account for the most important factors in strategic air warfare, the psychological and social effects of nuclear attack, not only on those the weapons are inflicted upon, but also on those doing the inflicting, if only because these factors could not be adequately calculated.[131]

Until the late 1950's, plans for nuclear warfare were almost exclusively the responsibility of SAC, in large part because of SAC's unique computing capabilities, designed specifically for the extremely complex nuclear targeting problem.[132] As such, strategic targeting plans through the 1950's embodied SAC's preference for spasmodic violence to paralyze Soviet society, for the application of absolute destruction to overcome the uncertainty of cause and effect. In 1959, the Joint Strategic Target Planning Staff (JSTPS) took on the responsibility of coordinating the several emerging

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[128] Dan Dyer, "Horizontal Approach to Target Analysis," Air University Lecture, 12 December 1951, 7. AFHRA file no. K239.716251-55. Quoted in Crane, *American Air Power Strategy in Korea*, 11.
[129] As Mark Clodfelter notes, "In their attempt to discover the key ingredients for successfully applying air power, air planners created a rigid formula for success that eliminated such variables as war aims and the nature of the enemy's military effort." Clodfelter, *The Limits of Air Power*, 36.
[130] Aaron L. Friedberg, "A History of the U.S. Strategic 'Doctrine' – 1945 to 1980," *Journal of Strategic Studies* (December 1980), 46. McMullen, *The United States Strategic Bombing Survey and Air Force Doctrine*, 50. Futrell, *Ideas, Concepts, Doctrine*, 237-239.
[131] Brodie, *War and Politics*, 476.

sources of nuclear striking power in each of the services to develop more flexible nuclear options. The JSTPS developed two aspects of nuclear targeting, the National Strategic Target List (NSTL) and the Single Integrated Operational Plan (SIOP), a family of highly detailed plans originally intended to give greater flexibility in the use of nuclear weapons, but whose deterministic calculations in reality limited the breadth of military possibilities by dictating force structures, military preparation, and the focus of strategic thinking.[133]

Like AWPD/1, the SIOP represented a crystallization of air power theory that mechanically applied nuclear air power to a list of discrete targets, aiming for an assurance of delivery factor of 97% for the first 200 targets and 93% for the next 200 targets.[134] Unlike AWPD/1, the SIOP's efficient calculations of effects were thankfully never put to the test and its analytical accuracy can only be surmised. Lacking an accurate gage for effectiveness, planners and operators substituted measures of friendly effort, much like operations analysts in the Second World War and Korea used bomb tonnage dropped instead of actual effects. In the era of the SIOP, friendly effort was couched in terms of "reliability" and the precise performance of the synchronized movements demanded by operational plans. Measures of effectiveness were thus divorced from ultimate strategic and political objectives and tied instead to the ability to execute a predetermined plan against an unresponsive opponent.

The precision of nuclear planning, however, was contingent on a complex mix of factors, many the end products of other dynamic and nonlinear processes. The difficulties of gauging both friendly and enemy will have already been mentioned above. The psyche of populations and leaders was in large part dependent on the technological

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[132] Rosenberg, "The Origins of Overkill," 37-38.
[133] Friedberg, "A History of the U.S. Strategic Doctrine," 42-43.

capabilities of defense, which were similarly difficult to accurately estimate. One of the most important limitations to nuclear planning was the inadequacy of targeting intelligence. Early planners relied on pre-World War II and even Tsarist era maps of the Soviet Union in addition to a few German aerial photographs from 1942-1943. In Project WRINGER, analysts also used interrogations of repatriated prisoners of war from the USSR as a primary source of target information.[135] Not until the introduction of U-2 over-flights in 1956 and the use of reconnaissance satellites after 1960 could the United States actually pinpoint potential targets in the Soviet Union. This lack of targeting information was one of the factors behind SAC's early preference for horizontal targeting of urban areas since large cities were the easiest to find and destroy with any measure of certainty.[136]

Rather than being independently determined, American plans for nuclear air power were interdependent with Soviet capabilities and intentions. Before the Soviets detonated a fission device in 1949 and a fusion device in 1953, American strategy centered on massive strikes against population centers to deter conventional Soviet aggression. As Soviet weapons and delivery capabilities improved, especially with the quicker-than-expected growth of a nuclear-capable bomber fleet, American planners turned increasingly to counterforce options that included the destruction of airfields and aircraft. The crisis inspired by the surprise launch of Sputnik in 1957 shocked the American system into greater emphasis on ballistic missiles and a strategy of survivability and massive retaliation to deter Soviet preemption.[137] More than just the

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[134] Rosenberg, "The Origins of Overkill," 3-7.
[135] Rosenberg, "The Origins of Overkill," 15 and 22.
[136] Friedberg, "A History of the U.S. Strategic Doctrine," 40-41.
[137] Futrell, *Ideas, Concepts, Doctrine*, 538-539.

result of straightforward calculations of cause and effect, American nuclear targeting emerged from a process of coevolution with a competing Soviet system.

Uncertainty about the effects of nuclear weapons and the overestimation of Soviet capabilities created an insatiable appetite for huge arsenals of nuclear weapons. The availability of greater targeting information did not simplify the problems of nuclear strategy, but instead created an even greater array of targeting possibilities, vastly complicating target lists while increasing the means required to "service" these lists. The growth of the bomber force was almost directly proportional with the growing size of target lists. At its heyday in 1959, SAC had more than 500 B-52s, 2,500 B-47s, and more than 1,000 supporting tanker aircraft.[138] The end result of this dynamic, the resulting debates over the questions of "sufficiency" and "overkill," cast further doubt on the "efficiency" of American nuclear strategy and its military cost. "How many times," as Eisenhower asked, "do we have to destroy the Soviet Union?"[139]

By the beginning of the Vietnam War, Air Force doctrine centered on strategic nuclear warfare against the war-making potential of a modern industrial nation with little provision for strategic bombardment using conventional weapons.[140] Military strategists in general and airmen in particular saw nuclear weapons as more efficient than "iron bombs," if not in the accuracy and discrimination they afforded, then in the decisive effects they could render.[141] But as Henry Kissinger later related, "We added the atomic

[138] Rosenberg, "The Origins of Overkill," 22-23 and 49-50.
[139] Eisenhower quoted in Builder, *The Icarus Syndrome*, 182.
[140] Crane, *Bombs, Cities and Civilians*, 150. See also Dennis Drew, *ROLLING THUNDER 1965: Anatomy of a Failure* (Maxwell AFB, AL: Air University Press, 1986), 24-27; and Futrell, "The Influence of the Air Power Concept on Air Power Planning," 269.
[141] "We will carry out any instruction given and we can fight an iron bomb war if that is what the President says he wants us to do.... We can only say if you want to destroy targets efficiently, we can do it better with a nuclear bomb." Lt. Gen. Charles S. Irvine, Deputy Chief of Staff for Materiel, before 1960 House Appropriations Committee. Quoted in Futrell, *Ideas, Concepts, Doctrine*, 617.

bomb to our arsenal without integrating its implications into our thinking."[142] Like the interwar doctrine for high-altitude precision daylight bombing, strategic nuclear bombing was reductionist in that it focused on a single aspect of air power at the expense of a more holistic consideration of other, more limited and discriminate capabilities.

The limited war in Korea from 1950-1953 opened a potential window on the limitations of a strategy that relied solely on nuclear warfare. Fighting with expectations for a future nuclear conflict against the Soviets ever in their minds, airmen, however, saw the conventional conflict in Korea, as General Weyland put it, as "kind of an anomalous type of war."[143] But the air war in Korea, as the war in Vietnam would later confirm, was anything but an anomaly and held many lessons about the difficulties of precision in the nonlinear environment of air warfare.

The Korean Anomaly

The Korean War was for the American military an unexpected kind of war waged in an unexpected place.[144] American airmen, their attention focused on the still-emerging doctrine for total war with nuclear weapons, instead found themselves fighting an air war in a much more circumscribed context.[145] As the North Korean invasion drove United Nations' forces back toward the Pusan Perimeter in the summer of 1950, battlefield necessities obliged the Far East Air Force (FEAF) to forego independent strategic

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[142] Henry A. Kissinger, *Nuclear Weapons and Foreign Policy* (New York: Harper and Brothers, 1957), 12.
[143] U.S. Air Force Oral History Interview, Gen. O. P. Weyland, 263.
[144] On American air power in the Korean War, see especially Conrad Crane, *American Airpower Strategy in Korea, 1950-1953* (Lawrence, KS: University Press of Kansas, 2000). The official Air Force history of the conflict is Robert F. Futrell, *The United States Air Force in Korea*, revised ed. (Washington, D.C.: Office of Air Force History, 1983).
[145] Clodfelter, *The Limits of Air Power*, xii and 10-26. See also Brodie, *War and Politics*, 57-107.

bombing in favor of close air support and battlefield interdiction to buoy beleaguered land forces.

Air superiority over the meager North Korean air forces came relatively easy. Under the umbrella of air supremacy, tactical aircraft and light bombers of the 5th Air Force provided air support and interdiction in South Korea while B-29 "medium" bombers of the FEAF Bomber Command attacked rail and road lines north of the 38th parallel to cut the lifelines of the North Korean forces.[146] Despite inadequate range from Japanese bases and the lack of training in close support missions, both air forces made significant contributions to stabilizing the front lines around the Pusan Perimeter and then creating the conditions for the subsequent advance northward. By the end of August, the 5th Air Force, with the help of naval aircraft from Task Force 77, claimed to have established forty-seven rail cuts, dropped ninety-three highway bridges around the perimeter, and left 140 other bridges between Seoul and the front lines unserviceable.[147] The air forces, by preventing the use of railroads and travel by road during the daytime, imposed significant logistical burdens on North Korean forces.[148]

While successful attacks on supply lines and enemy forces in close proximity to U.N. forces required precision attacks, the FEAF, at the request of General MacArthur, also resorted to carpet-bombing to stem the tide of the invasion. With the enemy threatening the important road junction of Taegu in the South, ninety-eight B-29s saturated a 27-square mile area with 960 tons of explosives in less than half an hour on 16 August. MacArthur wanted a second bombardment in the same area, but his reluctant

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[146] The aging B-29's, once designated "very heavy" bombers, were labeled "medium" bombers after Strategic Air Command's acquisition of the giant B-36. Crane, *American Airpower Strategy in Korea*, 21.
[147] Futrell, *The United States Air Force in Korea*, 131.

air commanders successfully convinced MacArthur that blindly dumping bombs across the countryside was having less effect than the interdiction campaign to the north.[149]

With the turn of tide in the land battle after the Inchon landing in September, the doors opened for a wider employment of air power. Having suffered through the alleged misuse of B-29's "never intended to be used against tactical targets," air planners using bomb groups borrowed from Curtis LeMay's Strategic Air Command (SAC) to supplement FEAF's Bomber Command fell back on the familiar pattern of "strategic" bombing against an opponent's industrial web.[150] But the true industrial strength of Communist forces in Korea lay across the Yalu River in Manchuria and the Soviet Far East, beyond the authorized reach of American bombers. With the few worthy industrial targets in North Korea systematically destroyed and the steady advance of United Nations forces further limiting available targets, Bomber Command stood down on 27 October.[151] The success of bombing was easily explained. "Our bombing should have been good," wrote one operational commander. "We didn't have any opposition and the bombardiers had all the time in the world to make their bomb runs."[152]

The intervention of Chinese Communists only days later presented an entirely new situation for American air power. With the surprise appearance of Chinese MiG-15's, a jet aircraft that outclassed F-51s and F-80s and was often flown by experienced

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148 Eduard Mark, *Aerial Interdiction in Three Wars* (Washington, D.C.: Office of Air Force History, 1994), 280-285.

149 Wayne Thompson, "The Air War Over Korea" in Bernard C. Nalty, ed., *Winged Shield Winged Sword: A History of the USAF*, Vol. II, 1950-1997 (Washington, D.C.: Air Force History and Museums Program, 1997), 15-16.

150 Curtis E. LeMay and MacKinlay Kantor, *Mission with LeMay* (Garden City, NY: Doubleday, 1965), 429. See also Futrell, *The United States Air Force in Korea*, 93-94.

151 Otto. P. Weyland, "The Air Campaign in Korea," in Eugene M. Emme, ed., *The Impact of Air Power* (Princeton, NJ: D. Van Nostrand Company, Inc., 1959), 386-387.

152 Col. James V. Edmundson, Commander, 22nd Group, quoted in Futrell, *The United States Air Force in Korea*, 195.

Soviet pilots, the FEAF no longer held uncontested control of the skies over North Korea.[153] Forced back into the role of "an expensive substitute for artillery fire," U.N. air forces turned to previously prohibited measures like the use of incendiaries and the bombing of crossing sites over the Yalu River in the north.[154] But the least discriminate method of attack, the use of nuclear weapons, remained off the table both for ethical reasons as well as the incalculable strategic and political consequences of their use.

As the front lines stabilized in the vicinity of the 38th parallel in the summer of 1951 (thanks in no small part to the persistent application of air power), American air planners turned to interdiction attacks against transportation targets in North Korea to cut Communist forces from their sources of material strength. The interdiction operation occurred in two stages: an operational interdiction campaign against roadways and rail centers north of the fighting fronts from May to August 1951 and a broader strategic interdiction campaign against rail lines further to the North from August 1951 to June 1952. Both of these campaigns went by the familiar code name STRANGLE, harkening back to successful aerial interdiction on the Italian Peninsula during World War II. Although tactically successful – the FEAF and Navy combined created over 22,000 rail cuts and damaged or destroyed more than 5,000 bridges, 2,300 locomotives, 41,000 rail cars, and 111,000 other vehicles – interdiction attacks were unsuccessful at bringing about desired strategic and political outcomes. Chinese troops and equipment still

[153] Futrell, *The United States Air Force in Korea*, 244; and Thompson, "The Air War Over Korea," 29. On Soviet participation in the air war over Korea, see especially Stephen J. Zaloga, "The Russians in MiG Alley," Air Force Magazine (February 1991), 74-77.
[154] Weyland, "The Air Campaign in Korea," 394. Crane, *American Air Power Strategy in Korea*, 8-9.

flowed, less freely but nevertheless sufficiently to maintain static defensive positions along the 38th parallel.[155]

Having failed to "strangle" North Korea through interdiction, the air forces under the new U.N. commander General Mark W. Clark resorted to "saturation" and "aerial pressure," bombing hydroelectric power plants in the summer of 1952. Although North Korea experienced a near total loss of power for two weeks and the electrical system never fully recovered for the remainder of the war, the attacks failed to bring progress at the peace talks at Panmunjon.[156] Frustrated by the lack of progress, the newly elected Eisenhower administration in the spring of 1953 demonstrated its willingness to expand the war by bombing irrigation dams and cities across North Korea. Broken dams not only flooded rice crops, but also washed out transportation arteries. "The damage done by the deluge," declared one 5th Air Force report, "far exceeded the hopes of everyone."[157] Pressed by the threat of atomic warfare, the death of Stalin in Russia, and the steadily accumulating costs of fighting, the North Korean and Chinese governments agreed to a somewhat imperfect peace in July 1953.

Although improved precision in air warfare is a natural trend and deliberate imprecision is rarely a goal, there were many factors in the Korean War that accelerated the push for greater bombing accuracy. The rugged geography of Korea that provided natural refuge to enemy troops and equipment was the first factor promoting more precise delivery of air to ground weapons. As the war stabilized into closely proximate opposing lines, area bombing no longer sufficed. The concern for friendly casualties also extended

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[155] Weigley, *The American Way of War*, 392; and Robert A. Pape, *Bombing to Win: Air Power and Coercion in War* (Ithaca, NY: Cornell University Press, 1996), 149 -151.
[156] Thompson, "The Air War Over Korea," 45-46.
[157] Futrell, *The United States Air Force in Korea*, 666-672.

to friendly prisoners of war held in North Korea – where the location of prisoner camps was known, air strikes were either prohibited or carefully placed to avoid collateral effects. Political factors demanded vigilant discrimination in air attacks as Communist propaganda fed on inadvertent collateral damage. The nature of target systems selected for attack also drove the need for tactical precision as bridges, rail lines, tunnels, and dams were exceedingly difficult to hit and destroy.[158] Well-constructed, seemingly "elastic" bridges built by Japanese occupation forces during World War II were especially resilient to attack, requiring pinpoint strikes against pilings and other weak points to bring them down.[159]

Improvements in bombing accuracy were, however, dependent on a complex mix of factors, some outside the prediction and control of air planners. The same political limitations that created a demand for bombing precision also worked against its achievement. Accurate bombing of bridges required B-29s to maintain straight and level flight, but this made it impossible to comply with restrictions imposed by the Joint Chiefs of Staff concerning over flight of Chinese and Soviet territory along the winding course of the Yalu River.[160] Faced with the military necessity of stopping the flow of Chinese soldiers across the Yalu, MacArthur turned instead to Navy Skyraiders and F4U Corsairs. More precise and therefore more appropriate for politically sensitive targets, these aircraft were nevertheless smaller and delivered an inadequate punch.[161]

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[158] See U.S. Air Force Oral History Interview, Gen. O. P. Weyland, 19 November 1974, 114. AFHRA file no. K239.0512-813. See also "The Attack on the Irrigation Dams in North Korea." *Air University Quarterly Review* 6 (Summer 1953), 40-61.
[159] Futrell, *The United States Air Force in Korea*, 130.
[160] Judy G. Endicott, ed., *The USAF in Korea: Campaigns, Units, and Stations, 1950-1953* (Washington, D.C.: Office of Air Force History, 2001), 15.
[161] Weigley, *The American Way of War*, 389-390.

Problems with target selection and identification were perhaps the most important limitation to precision early in the war. The FEAF had not prepared dossiers for targets on the Korean peninsula before the war. The first GHQ Target Group, a hastily organized part-time staff of four officers, relied on outdated and inaccurate maps and had little appreciation for the objectives of air strategy beyond the immediate need to support the ground troops.[162] Of the 220 targets this group designated, some twenty percent turned out to be nonexistent. Targeting improved with the formation of the FEAF Formal Target Committee in August 1951, but incomplete and inaccurate intelligence continued to plague air planners throughout the war.[163]

Thanks to the military drawdown after World War II and the benign neglect of conventional strategic bombing, Americans entered the Korean War with the same basic weapons they had used in World War II.[164] The B-26 Intruder, the primary light bomber in Korea, and the B-29 Superfortress, an old workhorse from the war often brought back to life at the hands of recalled reservists, relied primarily on visual bombing using Norden M-9 bombsights developed in the 1930's.[165] The complexity of the Norden bombsight, despite or perhaps because of the age of the technology, challenged hastily retrained aircrews. In November 1951, American B-26's switched to British Mark 9 fixed-angle bombsights that were easier to use. These too proved just as inaccurate as the

[162] Roger F. Kropf, "The U.S. Air Force in Korea: Problems that Hindered the Effectiveness of Air Power," *Airpower Journal* (Spring 1990).
[163] Futrell, *The United States Air Force in Korea*, 50-55 and 186-187. See also Crane, *American Air Power Strategy in Korea*, 33-34.
[164] Blackwelder, *The Long Road to Desert Storm and Beyond*, 17.
[165] According to a survey completed in 1952, only fifteen percent of the officers in FEAF were regulars. Crane, *American Airpower Strategy in Korea*, 103.

Norden in the hands of hurriedly trained aircrews and were retired by the 5th Air Force in May 1952.[166]

Accurate bombing required visual conditions, but clear weather was a rare occurrence over Korea, especially during the summer months. Because of Korea's geography – a peninsula covered by mountains with warm ocean currents on three sides – and weather fronts that flowed from China and the Soviet Union toward the south, forecasters found it difficult to predict favorable weather.[167] Communist forces timed offensives to coincide with seasonal periods of bad weather when close air support was most difficult. On the other hand, clouds blanketing hostile defenses around key transportation and industrial targets further north provided a measure of protection to FEAF bombers guided by electronic navigation aids.[168] Cloud cover thus discouraged discriminate tactical bombing while encouraging the use of less precise strategic attacks.

The AN-APQ/13 radar, another holdover device from the campaigns against Germany and Japan, offered the first alternative to visual bombing. Many of the B-29's in the FEAF were not equipped with the APQ-13, however, at the start of the war. Because the set depended on sharp radar contrasts and skilled operators for accurate target identification, blind radar bombing in Korea was still just as inaccurate and inefficient as it had been during World War II, especially in the North amidst strong enemy defenses. And just as in World War II, the use of radar tended to drive target selection, as clearly identifiable targets along rivers and coastlines were chosen over potentially more lucrative but harder to identify sites. Planners selected industrial targets

[166] Futrell, *The United States Air Force in Korea*, 455 and 461.
[167] Futrell, *The United States Air Force in Korea*, 65-66.
[168] Futrell, *The United States Air Force in Korea*, 616.

in the Hungnam area in the summer of 1951, for example, based upon land and water contrasts that made them good radar targets.[169]

A more accurate alternative to visual bombing was SHORAN (Short-Ranged Air Navigation radar). SHORAN paired radar ground beacon stations with an aircraft transceiver to triangulate an accurate positional fix for navigation guidance. First developed for use in Europe in 1945 and employed in Korea as early as October 1950, it was not until February 1951 that B-26 crews were successfully using SHORAN for bombing through the clouds and at night. By March 1951, SHORAN training took precedence over all other types of electronics training and training sorties were frequently combined with operational missions.[170] After successful tests in June 1951, B-29's also began flying SHORAN missions. Like other successful technologies, SHORAN was not without its limitations. These included limited range, higher flight altitudes required to receive the signal, and limited equipment availability. B-29's flying close to SHORAN transmission arcs were more predictable, and therefore more vulnerable to interception, in their approach to targets. Inaccurate maps further compounded the problem, as targets were often not at the exact coordinates indicated on maps.[171] Despite these shortcomings, operations analysts from the FEAF calculated that by September 1951 the use of SHORAN had cut B-29 circular error probable to 485 feet.[172]

Another successful use of radar was the use of AN/MPQ-2 radars (an updated version of a gun laying radar from the war in Europe) on the ground to guide aircraft onto

[169] Futrell, *The United States Air Force in Korea*, 188-190.
[170] History of the 731st Bombardment Squadron, March 1951, in "Early Days of Korean Conflict taken from Balchen Collection, Part I." AFHRA file no. 168.7053-3332, part 1.
[171] Futrell, *The United States Air Force in Korea*, 417.
[172] Futrell, *The United States Air Force in Korea*, 408-409 and 416-418. An example of a successful attack using SHORAN, on 23 September 1951 8 B-29's from the Bomb Group knocked out the center span of the Sunchon rail bridge despite 9/10 cloud cover. Warnock, ed., *The USAF in Korea*, 51.

enemy positions. Ground controllers vectoring B-26s and B-29s to targets in close proximity to friendly forces even told aircrews when to open bomb bay doors, arm bombs, and drop their weapons over release points.[173] As a 5th Air Force study titled "Pinpoint" later showed, however, ground radar controlled bombing was suitable only for relatively large area targets, having an average circular error probable of 1,177 feet for the B-26 and 1,300 feet for the B-29.[174]

Radar guidance put airplanes over target. Once over the target, weapons guidance helped put bombs on target. The only guided weapon in quantity production after World War II was the VB-3 RAZON, a free-falling 1000-pound bomb equipped with radio and flare for both azimuth and range guidance, that had been developed during World War II but never employed operationally.[175] After the war, the 1st Experimental Guided Missiles Group at Eglin Field modified the RAZON using the Norden bombsight for better tracking and guidance. In testing, the updated RAZON proved to be more accurate in azimuth than in range, making it more suitable for long and narrow targets like rail lines and bridges than point targets like buildings. The first B-29 RAZON mission over Korea occurred on 23 August 1950.[176] During the last four months of 1950, bombers destroyed fifteen bridges in Korea using RAZON bombs. All told, the 19th Bomb Group (one of the first groups equipped with the RAZON in 1949) dropped a total

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173 Futrell, *The United States Air Force in Korea*, 355-357.
174 Futrell, *The United States Air Force in Korea*, 542-543.
175 On testing of the RAZON and TARZON bombs, see "History of the 1st Experimental Guided Missiles Group," Eglin AFB, FL, 1 January 1949 – 30 June 1949, 10-11. AFHRA file no. GP-MI-1-HI. See also Gillespie, *Precision Guided Munitions*, 82-87.
176 A. Timothy Warnock, ed. *The USAF in Korea: A Chronology, 1950-1953* (Washington, D.C.: Air Force History and Museums Program, 2000), 13.

of 489 RAZONs, only 331 of which were controllable.[177] As Maj. Gen. Weyland, then Vice Commander for Operations in FEAF, commented in October 1950, "Razon bombing has been unsatisfactory. Bomb controls have not functioned, apparently because of age in storage."[178] In December 1950, with crews complaining not only of the inaccuracy of the bomb but also about the additional training and inordinate workload generated by the still experimental project, FEAF suspended the use of the RAZON in Korea.

The suspension also coincided with the arrival of a potentially more destructive and reliable guided bomb, the 12,000-pound VB-13 TARZON.[179] The TARZON, at twenty-one feet in length, was essentially an enlarged version of the RAZON that required a specially modified B-29 for delivery. Of the thirty-three combat missions flown using TARZON starting in December 1950, twenty-seven were deemed successful attacks, taking out several bridges and scoring a direct hit on a hydroelectric installation.[180] Like the RAZON, the TARZON required visual meteorological conditions, straight and level flight during bomb fall, and a drop altitude of 17-20,000 feet – all conditions that increased the vulnerability of the bomber to enemy fighters. The experimental bomb, itself, was also somewhat less than reliable. Within the first twenty-eight combat drops by the 19th Bombardment Group, five bombs were completely

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[177] HQ 19th Bombardment Group, Special Projects Section, "Combat Employment of Tarzon and Razon Guided Missiles," 31 August 1951, v. 3, 6. AFHRA file no. K240.01. Futrell, *The United States Air Force in Korea*, 320.

[178] O. P. Weyland, "Some Lessons of the Korean War and Conclusions and Recommendations Concerning USAF Tactical Air Responsibilities," 10 October 1950, in "Early Days of Korean Conflict taken from Balchen Collection, Part I." AFHRA file no. 168.7053-3332, part 1.

[179] Gillespie, *Precision Guided Munitions*, 81-94. The TARZON took the first two letters of its name from the oversize British TALLBOY bomb it was built around.

[180] Blackwelder, *The Long Road to Desert Storm and Beyond*, 20-21; Gillespie, *Precision Guided Munitions*, 82-94. The official Air Force history reports the final tally as: Thirty TARZONs dropped, six bridges destroyed, one bridge damaged, three duds, and nineteen missed targets. Futrell, *The United States Air Force in Europe*, 322-323.

unstable, sixteen were uncontrollable, there were thirteen flare failures, and only six bombs were determined to have actually destroyed their targets.[181] A crucial design flaw on the bomb surfaced on an ill-fated mission against Sinuiju on 19 March 1951 when a B-29 was destroyed after the TARZON it was carrying exploded after being jettisoned in preparation for ditching, killing the entire crew to include the commander of the 19th Bombardment Group.[182] This flaw was confirmed when another jettisoned TARZON, thought to have been "safed," exploded just seconds after impact with the water.[183] Given the apparent danger to aircrews, the extraordinary effort required to modify scarce B-29s, and the lack of targets requiring such a large bomb, the TARZON program was suspended in May 1951. In August, the RAZON-TARZON experiment was abandoned completely; by 29 October all of the guided bombs and associated equipment had been returned from operational units to the Air Proving Ground in Florida for future research and testing.[184]

What is perhaps most apparent in the study of air power in Korea, and perhaps least credited by American air power historians, is that the frustrations of American air strategy in Korea were as much a function of the success of Chinese strategy as they were an American failing.[185] Just as with the interaction with the Luftwaffe in 1944, the ability to strike targets precisely was contingent on the reactions of an able opponent.

[181] HQ 19th Bombardment Group, "Combat Employment of Tarzon and Razon," 6.

[182] The last radio message received from the plane stated it was returning to Okinawa with two engines out at 2000 feet. Despite a week long search, no trace of the missing bomber or its crew of twelve was ever found. From *The History of the 20th Air Force*, 1 January – 30 June 1951, 25 cited in "Early Days of Korean Conflict taken from Balchen Collection, Part I." AFHRA file no. 168.7053-3332, part 1. See also *Steadfast and Courageous: FEAF Bomber Command and the Air War in Korea, 1950-1953* (Washington, D.C.: Air Force History and Museums Program, 2000), 33-34.

[183] Futrell, *The United States Air Force in Korea*, 321-322.

[184] Blackwelder, *The Long Road to Desert Storm and Beyond*, 21.

[185] Mark, *Aerial Interdiction in Three Wars*, 318-319. See also Crane, *American Air Power Strategy in Korea*, 82-83.

Communist ground forces quickly adapted to the U.N. aerial interdiction campaign by moving only at night. After Chinese MiG-15s downed five B-29s in a single week in October 1951, Bomber Command began bombing almost exclusively under the cover of darkness.[186] The B-26 and the B-29, however, were ill equipped for the demands of nighttime operations.[187] For example, B-26s of the 47th Group of the Fifth Air Force responsible for tactical bombing in Korea flew early night sorties without radar altimeters or radar navigation and targeting devices essential for accurate night bombing.[188] Night conditions, complicated by inclement weather, also made it more difficult to analyze the effects of bombing. "We can go out night after night and come home and not be too sure what we have done," remarked one airman. "We are not able to measure our effectiveness."[189]

Tactical adaptations for greater precision at night included the use of illuminating flares and "buddy system" tactics for target identification and destruction, first in B-26's and then in B-29's. When more than half of Air Force issued flares failed to illuminate, the FEAF borrowed more reliable flares from the Navy to be dropped from C-47 cargo planes, but the vulnerability of the C-47 limited its range to no more than twenty or thirty miles north of the battle line. Whatever their utility, the use of flares was also dangerous for aircrews as they frequently caused night blindness and exposed illuminated bombers to anti-aircraft fire.[190]

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[186] Thompson, "The Air War Over Korea," 41.
[187] Mark, *Aerial Interdiction in Three Wars,* 298-300. Gregory A. Carter, *Some Historical Notes on Air Interdiction in Korea*, RAND Report No. P-3452 (September 1966), 15-16. Carter also mentions a brief experiment named REDBIRD that matched an early version of infrared equipment with a B-26.
[188] Futrell, *The United States Air Force in Korea*, 135.
[189] Quoted in Futrell, *The United States Air Force in Korea*, 454.
[190] Mark, *Aerial Interdiction in Three Wars,* 305-306.

The much-touted quantitative ratio of 13:1 American to Chinese aerial victories obscures the intangible ways in which the enemy succeeded in frustrating American air power.[191] Operational analysis reports that showed higher losses at low altitudes drove bombers to higher altitudes, with a subsequent loss of accuracy. The increasing threat from automated air defenses and Chinese MiGs (despite the successful introduction of the American F-86) put critical bridges in the north beyond the reach of American bombers. In November 1950, Bomber Command stopped sending B-29s into "MiG Alley" in the north because of escalating losses. After attempting to renew the effort in March 1951, further losses (the Chinese now had as many as 445 MiG-15s available over the North) led to the prohibition of unescorted bomber missions in June.[192] Even when accompanied by fighter escorts, B-29 operations in the north were limited only to nighttime after October 1951.

To counter the success of American SHORAN-guided bombing at night, Communist defenders covered SHORAN arcs with radar-controlled searchlights and flak batteries.[193] With the B-29's failing to meet expectations, Americans increasingly turned to fighter-bombers like the F-80 and the F-84. But communist defenses affected the methods of tactical aircraft as well, forcing fighter-bombers to expend resources to suppress defenses, fly at higher altitudes, and use dive-bombing instead of glide-bombing

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[191] The ratio also obscures the ways in which many of these victories were won and American overestimation of enemy losses. Recent scholarship argues that many of the kills occurred against Chinese and Russian aircraft during takeoff and landing from fields north of the Yalu River and that in the skies over Korea, Communist (especially Russian) and American pilots were more evenly matched than has been portrayed. See Xiaoming Zhang, *Red Wings Over the Yalu: China, the Soviet Union, and the Air War in Korea* (College Station, TX: Texas A&M Press, 2002), 4-5 and 122-145.
[192] Futrell, *The United States Air Force in Korea*, 285.
[193] Futrell, *The United States Air Force in Korea*, 424-425.

as a measure of protection, effectively cutting bombing accuracy in half.[194] American responses included the increased use of electronic counter measures and painting the bellies of B-29s black to prevent illumination by searchlights.[195] Fearful of divulging technological secrets that might prove essential in a general war against the Soviets, the FEAF, however, limited the use of more sophisticated electronic counter measures.[196]

Other Chinese adaptations that contributed to the diminution of air power success included the use of cover and concealment and the enlistment of peasant labor to repair rails, roads, and bridges faster than bombers could destroy them.[197] Effectiveness, then, was not simply a function of the tonnage of bombs dropped or even the efficiency and accuracy of air strikes. To take but one tactical example: during Operation SATURATE in the spring of 1952, as many as forty B-29s were used to bomb a single bridge and fighter-bombers dropped 500 or more bombs on a single stretch of track. Yet the combined strength of air power could maintain no more than six cuts on North Korea's main rail lines at any one time.[198] Like other military strategies, air power is never executed in isolation; its degree of success or failure hinges on the reactions of the opposing system. As General Hoyt Vandenburg noted, "the clandestine processes by which an ancient and industrially backward people had come so swiftly into possession of these costly weapons" surprised American strategists.[199] In Korea, American airmen

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[194] Mark, *Aerial Interdiction in Three Wars*, 312-313; Carter, *Some Historical Notes on Air Interdiction in Korea*, 10-11; Futrell, *The United States Air Force in Korea*, 519; and Crane, *American Air Power Strategy in Korea*, 136. On the development of dive-bombing in Korea and the difficulties of accuracy see Gillespie, *Precision Guided Munitions*, 77-79.
[195] Warnock, ed. *The USAF in Korea*, 69 and 73.
[196] Crane, *American Air Power Strategy in Korea*, 90.
[197] Warnock, ed., *The USAF in Korea*, 60. See also Weyland, "The Air Campaign in Korea," 396.
[198] Thompson, "The Air War Over Korea," 42.
[199] Hoyt S. Vandenburg, "Air Power in the Korean War," in Eugene M. Emme, ed., *The Impact of Air Power* (Princeton, NJ: D. Van Nostrand Company, Inc., 1959), 400-401.

failed to anticipate not only the war itself, but also the significant challenges that could be posed by an underestimated opponent.

The effectiveness of air power was also dependent upon the conduct of the ground war. Air interdiction was only successful when combined with ground maneuver that created additional demands on the enemy's logistical system. Not only military objectives and strategies, but also larger political goals and limitations, governed what was and was not possible for American air power in Korea.[200] As General Weyland astutely commented after the war, deriving "a pattern of employment" in a limited war with shifting military and political objectives "is a complex business." Mastering this complex business required an appreciation for the holistic and "indivisible" nature of air power, an appreciation that avoided "the confusion and misunderstandings" created by trying "to classify it by types of aircraft, types of operations, or types of targets."[201]

Conditioned by the strategic bombing campaigns of World War II, American airmen in the Korean War found themselves flying missions very different than those for which they had trained.[202] Constrained by the "frictions" of limited war, American air power in Korea achieved political and strategic outcomes disproportionately smaller than the effort applied and the cost sustained in lives and aircraft lost.[203] The American reaction to the experience was "never again." Written off as anomaly, airmen failed to grasp the importance of the lessons the Korea had to offer. Writing in 1955, the former Secretary of the Air Force, Thomas Finletter, concluded that the war had been "a special

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[200] In the words of Air Force historian Robert Futrell, "...the local peculiarities of the limited war did not permit a full exploitation of the strategic bombing function." Futrell, *Ideas, Concepts, Doctrine*, 349.
[201] Weyland, "The Air Campaign in Korea," 399-400. See also Futrell, *Ideas, Concepts, Doctrine*, 346-347.
[202] Approximately 30 percent of all sorties were flown in close support of ground forces, as opposed to roughly 10 percent during WWII. Weyland, "The Air Campaign in Korea," 398.

case, and air power can learn little from there about its future role in United States foreign policy in the East."[204] Although operations analysis had played an important role in the conduct of the war, the Air Force commissioned no formal postwar bombing survey.[205] Since the results of air power were less than decisive and a formal survey might emphasize the successes of tactical and not strategic air power, airmen preferred to simply put the experience aside.

When the Air Force finally rewrote its doctrine in 1953 (FM 100-20, the "Magna Carta" of independent air power from 1943, was still the governing document throughout the Korean War), the new crystallization of thinking on air power downplayed limited conventional war, focusing instead on air power's role in general nuclear war.[206] As one Air University study pointed out, since each limited war situation will be unique and it is hard to pinpoint where the next one might pop up, "generalization concerning the types of forces which could best be employed becomes exceedingly difficult."[207] The best way to avoid future Koreas then was to deter enemy aggression by being adequately prepared for general nuclear war.[208] Much of air power's influence in Korea, two airmen explaining the importance of the new doctrine concluded, "came from air forces that

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203 American air forces lost some 1200 airmen killed and 750 aircraft destroyed. Thompson, "The Air War Over Korea," 50.

204 Quoted in David MacIsaac, "The Evolution of Air Power Since 1945: The American Experience," in R. A. Mason, ed., War in the Third Dimension: Essays in Contemporary Air Power (London: Brassey's Defence Publishers, 1986), 17. For Finletter's sense of the urgent need for strategic nuclear air power, see especially Thomas K. Finletter, "Evaluation of the Air Weapon as Reflected in Assigned Roles," lecture at Air University, 17 November 1953. AFHRA file no. K239.716253-26.

205 Gentile, "Investigating Oneself," 13-14. On operations analysis during the war, see Crane, *American Air Power Strategy in Korea*, 59-62.

206 Futrell, *Ideas, Concepts, Doctrine*, 365-416. Crane, American Air Power Strategy in Korea, 175.

207 "The USAF in Limited War," Project No. AU-1-57-ESAWC, 20 March 1958. AFHRA file no. K239.042957-1.

208 As Curtis LeMay told Congress, "If you have the power to stop a big war, certainly the same power ought to be capable of stopping a small war." Quoted in Futrell, *Ideas, Concepts, Doctrine*, 358-359. See also Crane, *American Air Power Strategy in Korea*, 175; and Dennis M. Drew, "Air Theory, Air Force,

never dropped a bomb or fired a bullet in Korea." Although it may sit unused, the strategic air force's played the predominant role in defense as a "fleet in being."[209] In the wake of the Korean War, the United States Air Force wagered its future on strategic air power and nuclear weapons, leaving it unprepared for the next anomalous war in Vietnam.

Conclusion

Innovation during World War II and the early years of the Cold War provided new technological capabilities for the delivery of both conventional and nuclear weapons. Under Hap Arnold's wartime leadership, the Army Air Forces developed and employed several variants of glide bombs that aircrews could remotely guide to their targets. Although still imprecise and not very reliable, these new weapons represented the first generation of guided weapons that were to become the technological foundations of modern precision air power.

Efficiently managing the complexity of the new gizmos and gadgets required the dedicated application of the scientific method. However well the engineering approach of American operations researchers and scientists worked in analyzing the effects of air power during the war, in technological research and development, and in calculating future force requirements, it was a poor match for the intangibles of both conventional and nuclear military strategy, intangibles attributable to the nonlinear nature of warfare.

And Low Intensity Conflict: A Short Journey to Confusion," in Phillip S. Meilinger, ed., *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell AFB, AL: Air University Press, 1997), 321-356.

[209] Jerry D. Page and Royal H. Roussel, "Little Book with a Big Wallop," *Air Force Magazine* (January 1956). AFHRA file no. K168.91-2.

Science and quantification, as Zuckerman later noted, proved better aids than alternatives to military judgment.[210]

While the cultural, technological, and moral preference was for precision, the less discriminate nuclear alternative nevertheless held great appeal against foes with an overwhelming advantage in conventional forces. Although the destructive capabilities of nuclear weapons minimized the importance of absolute precision in weapons delivery, they did little to simplify the chains of causation between cause and effect in air warfare. Nuclear plans, centered on the quantifiable certainty of destruction, inadequately accounted for the intangible aspects of nuclear strategy – most importantly, both friendly and enemy will to put such destruction into effect. Nuclear air strategy, in the end, proved just as nonlinear and ultimately inefficient as conventional air strategy.

Although the post-war Air Force focused on strategic nuclear warfare, conventional tactical air power made the greatest contributions to success in Korea. The air war over Korea reconfirmed the politically contingent nature of warfare and the need for continuous operational adaptation. The constraints imposed on precision strategic bombardment by military realities on the ground and the political realities of the Cold War were not unique to Korea, but were an intrinsic and unavoidable aspect of modern warfare. Contrary to the tenets of strategic bombing doctrine, effectiveness required the persistent application of both tactical and strategic air power as a unified whole. Written off as irregularities that didn't fit scientific generalizations about air warfare, the lessons

[210] Zuckerman, *Scientists and War*, 26. Or put another way by Albert Wohlstetter in 1963, "The basic failure of the physical scientists and engineers in their turbulent history during the cold war is not their lack of prescience but their acting frequently as if they had it." Albert Wohlstetter, "Scientists, Seers and Strategy," *Foreign Affairs* 41/3 (April 1963), 478.

from Korea about the nonlinear nature of war had to be relearned once again in the skies over Vietnam.[211]

[211] On the repetitious nature of the lessons of air warfare, see William S. Momeyer, *Airpower in Three Wars: WWII, Korea, and Vietnam* (Washington, D.C: U.S. Government Printing Office, 1978), iv; Donald J. Mrozek, *Air Power and the Ground War in Vietnam: Ideas and Actions* (Maxwell AFB, AL: Air University Press, 1988), 22; and Robert F. Futrell, *Ideas, Concepts, Doctrine*, 1, 440-442.

SEEKING CLOCKS IN THE CLOUDS:

NONLINEARITY AND AMERICAN PRECISION AIR POWER

by

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Part II

Vietnam and Technological Precision

"Tools, or weapons, if only the right ones can be found, are ninety-nine per cent of victory."

J.F.C. Fuller, 1919[1]

The ROLLING THUNDER bombing campaign against North Vietnam from 1965 to 1968 was at best an indecisive test, and at worst, a clear failure of American conventional strategic air power. In contrast, the more concentrated and less restrained LINEBACKER I and LINEBACKER II campaigns in 1972 brought the North Vietnamese to the peace table, achieving the (admittedly limited) strategic goal of disentangling the United States from the conflict in Vietnam. Analysts, both in the Air Force and in the public at large, attributed success in the LINEBACKER campaigns to the absence of political restrictions on bombing and the technological "revolution" in precision guided munitions.[2] Whereas F-105 fighter-bombers toward the end of ROLLING THUNDER averaged a circular error probable of 447 feet with 5.5 percent of their bombs scoring direct hits, guided bombs dropped between February 1972 and February 1973 recorded an average error of twenty-three feet with forty-eight percent direct hits. One Air Force study claimed that it took seven times as many sorties and twenty-five times as many bombs to drop a bridge in ROLLING THUNDER as it did in LINEBACKER I.[3] The take-away lesson of the LINEBACKER campaigns (a lesson

[1] Quoted in Robert S. Jordan, *Norstad: Cold War NATO Supreme Commander* (New York: St. Martin's Press, Inc., 2000), 25.
[2] See for example John W. Finney, "Guided Bombs Expected to Revolutionize Warfare," *The New York Times*, 18 March 1974, 1. See also "U.S. Guided Bombs Alter Viet Air War," *Aviation Week and Space Technology* (22 May 1972), 16-17; and Earl H. Tilford, Jr., *Setup: What the Air Force Did in Vietnam and Why* (Maxwell AFB, AL: Air University Press, 1991), 238.
[3] Kenneth P. Werrell, *Chasing the Silver Bullet: U.S. Air Force Weapons Development from Vietnam to Desert Storm* (Washington, D.C.: Smithsonian Books, 2003), 152.

seemingly confirmed by DESERT STORM in 1991) was that strategic success was a direct consequence of the tactical accuracy of guided weapons.

Air power's success, however, depends on the operational context of its employment. Although both air campaigns had the common strategic objective of reducing North Vietnam's support to the insurgency in South Vietnam, there were considerable differences not only in weapons technologies, but also in operational conditions and most importantly, in the strategic and political environment.[4] Operationally mature precision weapons were an important technological breakthrough, the leading edge of a profound change in the character of warfare. The true precision of guided weapons held many advantages for air power. It is reductionist, however, to think that air power armed with new weapons was the primary cause of American extrication from Vietnam. Thinking in these reductionist terms misplaces the weight of strategy on the tools rather than on the conditions of war – like political aims and the nature of the opponent – and the utility of those tools to the task at hand.

Approaches to the Air War in Vietnam

Many of the defects in the conduct of the air war over Vietnam came from the differences in military and civilian conceptions of air power. The "Whiz Kids" of the Kennedy and Johnson administrations sought to change brute military force into a highly discriminate and controllable political instrument through a rational and graduated managerial approach.[5] Operations research and systems analysis, having grown from the need to manage increasingly complex technologies, gave the mathematical tools for more

[4] Mark Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam* (New York: The Free Press, 1989), 147-148.

precise solutions to longer-range problems of a much larger context.[6] For analysts with backgrounds in business management, military problems were "economic problems in the efficient allocation and use of resources."[7]

The ultimate attraction of air power for decision makers was its potential for careful central management. Unlike ground power, air power could be administered in precise doses that facilitated the use of force to achieve policy objectives.[8] Furthermore, air power seemed a cost effective way to achieve maximum output for minimum input while keeping the war at arm's length. Facing a deteriorating political situation in Southeast Asia, the costs of bombing and the "slow squeeze" of graduated reprisals seemed relatively cheap when measured against the political and strategic costs of losing South Vietnam.[9] For civilian decision-makers like economist Walt W. Rostow, a former member of the Enemy Objectives Unit who saw bombing as a kind of tax on the North, it was the efficiency and not necessarily the overall effectiveness of bombing that counted most.[10]

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[5] See Bernard Brodie, *War and Politics* (New York: Macmillan Publishing Co., Inc., 1973), 464-479.

[6] See especially Russell F. Weigley, *The American Way of War: A History of United States Military Strategy and Policy* (New York: Macmillan, 1973), 406. On the application of operations research to the air war in Vietnam, see especially I. B. Holley, Jr., "The Evolution of Operations Research and Its Impact on the Military Establishment: The Air Force Experience," in Monte D. Wright and Lawrence J. Paszek, eds., *Science, Technology, and Warfare: The Proceedings of the Third Military History Symposium, United States Air Force Academy, 8-9 May 1969* (Washington, D.C.: Office of Air Force History, 1970), 99ff.

[7] Charles J. Hitch and Roland N. McKean, *The Economics of Defense in the Nuclear Age* (Cambridge, MA: Harvard University Press, 1960) quoted in Herman L. Gilster, *The Air War in Southeast Asia: Case Studies of Selected Campaigns* (Maxwell AFB, AL: Air University Press, 1993), 31. Hitch and McKean's book played an important role in stimulating decision making in the Department of Defense based on economic principles.

[8] Larry Cable, *Unholy Grail: The U.S. and the Wars in Vietnam, 1965-8* (New York: Routledge, 1991), 30 and 87.

[9] See especially McGeorge Bundy, "A Policy of Sustained Reprisal," 7 February 1965, in *The Pentagon Papers: The Defense Department History of United States Decisionmaking on Vietnam* (The Senator Gravel Edition), 5 volumes (Boston: Beacon Press, 1971), 3, 312-315.

[10] Walt W. Rostow, *The Diffusion of Power* (New York: Macmillan, 1972), 509-512. See also Donald J. Mrozek, *Air Power and the Ground War in Vietnam: Ideas and Actions* (Maxwell AFB, AL: Air University

The most influential civilian throughout much of ROLLING THUNDER was Robert S. McNamara, who brought his background with statistical research on the effects of bombing in World War II and his experience as an executive at the Ford Motor Company to the job of Secretary of Defense.[11] The methods of ops research and systems analysis, pioneered by the Army Air Forces during the war, became almost a religion in McNamara's Department of Defense.[12] McNamara thought very highly of RAND and their pioneering work in game theory, estimating that the Air Force received "ten times the value of the money the Air Force invested in it."[13] General John Vogt, then Chief of the Policy Planning Staff at the Pentagon and later commander of the 7th Air Force during the LINEBACKER campaign recalled, "McNamara was a believer in the computer, and he was a believer in subjecting everything to detailed analysis. He thought there was always an empirical answer. The subjective stuff like 'military view' or somebody's experience didn't mean very much to him."[14] Under McNamara's influence, the objective and deterministic approach to military problems took hold of both civilian and military alike in the Department of Defense, from the highest levels of strategy to the smallest details of aerial analysis and targeting.

The ultimate military objective of bombing in Vietnam was not necessarily to win at all costs, but as McNamara told General Westmoreland in 1965, to cost-effectively

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Press, 1988), 182-183; Weigley, *The American Way of War*, 466ff, and Ulysses S.G. Sharp, *Strategy for Defeat: Vietnam in Retrospect* (Novato, CA: Presidio Press, 1998), 84 and 169-170.

[11] Clodfelter, *The Limits of Air Power*, 87-88. Weigley, *The American Way of War*, 446. See also George M. Watson, Jr. and Herman S. Wolk, "Whiz Kid: Robert S. McNamara's World War II Service," *Air Power History* 50/4 (Winter 2003), 4-15.

[12] Conrad C. Crane, *Bombs, Cities, and Civilians: American Airpower Strategy in World War II* (Lawrence, KS: University Press of Kansas, 1993), 151.

[13] Quoted in Alan L. Gropman, "Air Force Planning and the Technology Development Process in the Post-World War II Air Force – the First Decade (1945-1955)," in Harry R. Borowski, ed., *Military Planning in the Twentieth Century: The Proceedings of the Eleventh Military History Symposium, 10-12 October 1984* (Washington, D.C.: Office of Air Force History, 1986), 171-172.

"convince the enemy he would be unable to win" while at the same time avoiding a response from the Russians or Chinese.[15] The key operating assumption was that the conflict in South Vietnam was a partisan war supported by the North and not an independent, homegrown insurgency. Bombing the North demonstrated the United States' determination to support South Vietnam and their willingness to actively oppose North Vietnamese intervention. Air power, then, for the civilian leadership in the Johnson administration was a management tool to control an opponent's behavior by communicating intentions. The military effectiveness of bombing was less important than the signals bombing conveyed.[16]

The alternative, preferred by military leadership, was an air campaign cut from the mold of the campaigns against Germany and Japan. Airmen in particular, motivated by sunken costs already invested in training and resources, preferred a bombing campaign aimed at the "vital centers" of North Vietnam's industrial and transportation system.[17] Air commanders like General Curtis LeMay and Admiral Ulysses S. G. Sharp considered McNamara and the Whiz Kids "reckless amateurs" who lacked operational experience in the conduct of war, experience that had validated the doctrine of strategic bombing.[18] Like their civilian overseers, military planners saw efficacy in a strategic air

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[14] Gen. John W. Vogt, U.S. Air Force Oral History Interview, 8-9 August 1978, 48. AFHRA file no. K239.0512-1093. See also Holley, "The Evolution of Operations Research," 103.
[15] William C. Westmoreland, *A Soldier Reports* (New York: Dell Publishing Company, 1980), 543. Quoted in Dennis M. Drew, *ROLLING THUNDER 1965: Anatomy of a Failure*, Report No. AU-ARI-CP-86-3 (Maxwell AFB, AL: Center for Aerospace Doctrine, Research, and Education, 1986), 10-11.
[16] Cable, *Unholy Grail*, 206 and 236-237. See also Fred Kaplan, "All Pain, No Gain," *Slate* (11 Oct 2005), available at http://slate.msn.com/id/2127862/ (accessed 11 Oct 2005).
[17] Clodfelter, *The Limits of Air Power*, 73 and 125-128; Weigley, *The American Way of War*, 466.
[18] Carl Builder, *The Icarus Syndrome: The Role of Air Power Theory and the Evolution and Fate of the U.S. Air Force* (New Brunswick, NJ: Transaction Publishers, 1994), 182-183. As one Air Force analyst later put it, "Johnson's key civilian advisers did not understand how air power had contributed to victory in the Second World War.... They also would not listen to those who did." A. L. Gropman, "The Air War in Vietnam, 1961-1973," in R. A. Mason, ed., *War in the Third Dimension: Essays in Contemporary Air Power* (London: Brassey's Defence Publishers, 1986), 39. See also Sharp, *Strategy for Defeat*, 267-271;

campaign against the North. In 1964, planners from the Defense Intelligence Agency and the Joint Staff developed a 94-target list that reflected the military preference for an assortment of familiar targets like airfields, transportation, oil, and industrial sites "which experience has shown to be those required to meet the desired damage objectives in the most economical ways."[19] By 1967, this list had grown to 244 targets. Throughout the war, the American air forces flew the majority of their combat missions over South Vietnam, Laos, and Cambodia.[20] But their eyes were always on the North.

One important error in the formulation of national strategy, an error attributable to both military and civilian alike, was treating the Viet Cong insurgents in the South as if they were dependent on support from North Vietnam. In the early years of the war, the Viet Cong were more or less independent actors; severing the lifelines from the North would have little effect on the outcome of the conflict in the South. According to CIA analyses, North Vietnam was in fact in no position to provide military support to the insurgency in 1964 and it was only after American bombing that "there appear[ed] to be more enthusiasm for supporting the war in the South."[21] As Truong Nhu Tang, a former member of the National Liberation Front (NLF) in South Vietnam, writes, "One of the consequences of [American intervention] was that the NLF had been forced to rely to an ever greater extent on its Northern ally. ...As a result, the NLF had found itself ever more

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and Wayne Thompson, *To Hanoi and Back: The USAF and North Vietnam, 1966-1973* (Washington, D.C.: Air Force History and Museums Program, 2000), 21-22.

[19] Extracts from JCS Memorandum for Secretary of Defense, 24 August 1964. AFHRA file no. K178.2-34. For a critical analysis of DIA's role in targeting in Vietnam, see Patrick J. McGarvey, "DIA: Intelligence to Please," *The Washington Monthly* (July 1970), 68-75. McGarvey, a former analyst at DIA, claims that DIA was dominated by service cultures and was "too busy keeping up with the flow of numbers from Saigon" to consider more qualitative information, focusing not on effectiveness, but on finding "targets that a certain weapons system could attack."

[20] Only 6% of the bombs dropped by the 124,500 B-52 sorties in SE Asia (each dropping 30 tons of bombs) fell on North Vietnam, and only a small percentage of this 6% fell on the strategic Hanoi-Haiphong region. Gropman, "The Air War in Vietnam," 55.

obviously dominated by the Party and by the Northern government."[22] Rather than coercing desired behaviors, ROLLING THUNDER was itself a mechanism for the mobilization of political will and military resistance in the North.

The flaw in the military's concept for the air war was that it was derived from a schema for nuclear strategic bombing that had little applicability to a conventional counter-insurgency fought against a non-industrial opponent.[23] Instead of shaping their concept to match the unique operational environment, air commanders looked to mold the air war to the doctrine at hand, treating North Vietnam as a complex, industrialized country.[24] Some twenty years earlier, air power advocate Alexander de Seversky had warned against just such a mismatch: "Total war from the air against an undeveloped country or region is well nigh futile; it is one of the curious features of the most modern weapon that it is especially effective [only] against the most modern types of civilizations."[25] Success of the strategic air campaign, then, was contingent not only on the nature of the war, but also on the nature of target.

The Imprecision of ROLLING THUNDER

Despite military preferences, national political objectives (as the Joint Chiefs noted), "precluded the employment and applications of airpower in the classical sense."[26] While both sides saw air power as a cost-effective alternative, civilian political leaders rightly feared the higher order effects of the destruction sought by military commanders.

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[21] Cable, *Unholy Grail*, 79-80 and 115.
[22] Truong Nhu Tang, *A Vietcong Memoir* (New York: Vintage Books, 1986), 130-131.
[23] Clodfelter, *The Limits of Air Power*, 100-101.
[24] James William Gibson, *The Perfect War: Technowar in Vietnam* (New York: The Atlantic Monthly Press, 1986), 335 and 351.
[25] Alexander de Seversky, *Victory Through Air Power* (New York: Simon and Schuster, 1942).

Effectively hamstrung by their doctrine, the military failed to offer acceptable alternatives, leaving the questions of air strategy by default to their civilian masters.[27] The resulting ROLLING THUNDER campaign embodied the managerial approach, calculated not to threaten the North's survival, but to leave a "credible threat of *future* destruction [that made it] politically easy for the DRV to enter negotiations."[28] The formulation of air plans ran a convoluted path designed to carefully control the political effects of bombing – from the Joint Staff through the Secretary of Defense, Secretary of State, and the President (at the infamous Tuesday lunches) and then back down to Commander in Chief in the Pacific.[29] Under this politically constrained process, targeting became mechanical and deterministic and the air war devolved into predictable and therefore increasingly vulnerable routines.[30]

Given fears of Chinese involvement and the possibility of Soviet nuclear confrontation, precision, both in choosing as well as in striking discrete targets, was of utmost importance.[31] Indiscriminate strikes against the North were simply not an option. President Johnson personally cleared targets in the Hanoi-Haiphong area after the military benefits expected, probable losses, estimated civilian casualties, and the risks of damage to foreign interests had been systematically argued before him.[32] Occasionally, the White House removed targets from the Joint Chiefs' lists, despite their significance to the air plan, to avoid collateral effects that might weigh negatively in the battle for the

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[26] JCS briefing on air operations in North Vietnam and Laos, n.d. (1966?), 21. AFHRA file no. K178.2-34.
[27] G. Summers, Jr., *On Strategy: A Critical Analysis of the Vietnam War* (New York: Dell Publishing Co., Inc., 1982), 22 and 73-74. See also Brodie, *War and Politics*, 479-496.
[28] Robert S. McNamara memorandum to President Johnson, 30 July 1965, in *The Pentagon Papers* (Gravel edition), 3, 388. On the objectives of the ROLLING THUNDER campaign, see *ibid.*, 3, 269.
[29] Sharp, *Strategy for Defeat*, 86-87. Clodfelter, *The Limits of Air Power*, 84-88.
[30] Weigley, *The American Way of War*, 407ff.
[31] Bernard Appel, "Bombing Accuracy in a Combat Environment," *Air University Review* 26/5 (Jul-Aug 1975), 39.

hearts and minds of the Vietnamese people.[33] The political context drove air power toward greater precision and discrimination.

Although civilian strategists sought the efficient use of military force, their managerial approach proved strategically ineffective. Rational planning is not warfighting. McNamara's Planning, Programming, and Budgeting System, although useful in preparing for war, was, as Clausewitz noted about other refined mechanical methods, "about as relevant to combat as the craft of the swordsmith to the art of fencing."[34] Planners applied linear econometric models that called for easily quantifiable data "to help the target analyst and operational planner choose more nearly optimal target complexes."[35] Quantification dominated not only planning, but also assessment. The Defense Intelligence Agency, the primary military source of information during ROLLING THUNDER, relied on quantitative measures of destruction at the expense of more subjective analyses of bombing's effects, like the impact of bombing on Hanoi's strategy.[36] As RAND analyst Amron H. Katz commented in 1967, only the North Vietnamese could accurately tell the full effects of air power on their plans and operations.[37]

Unable to quantify *effects*, planners instead used statistical measures of *effort* like sortie generation rates to measure the air war's progress.[38] But effort did not immediately equate to effectiveness. Measures of effort intended as managerial tools for senior

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[32] Rostow, *The Diffusion of Power*, 510. Tilford, *Setup*, 111.
[33] Sharp, *Strategy for Defeat*, 127-128; Clodfelter, *The Limits of Air Power*, 104; and Cable, *Unholy Grail*, 97.
[34] Carl von Clausewitz, *On War*, Michael Howard and Peter Paret, eds. and trans. (Princeton: Princeton University Press, 1976), 133. Summers, *On Strategy*, 74-83.
[35] See for example Joseph Steele, "An Econometric Target Selection Model," Operations Analysis Headquarters, USAF, September 1967. AFHRA file no. K143.504-34.
[36] Clodfelter, *The Limits of Air Power*, 130.
[37] Futrell, *Ideas, Concepts, Doctrine*, 2, 319.

leaders became production quotas for operators in the field. The infamous Route Package System that divided North Vietnam into separate bombing zones was a measure that facilitated command and control, but also a way to allow each service to achieve its bombing quota.[39] These production quotas, intended to lend efficiency to the bombing campaign, in fact encouraged acts of inefficiency. When bombs were scarce, airplanes often flew with less than full loads to keep sortie counts artificially high.[40] As one pilot noted, "[I]t looks much better for the commander and the service concerned to show 200 sorties on paper, even when 40 or 50 would do the same job."[41]

There were other factors beyond politicized strategies and managerial methods that kept the air war from its Clausewitzean absolutes. The most important of these was the Air Force obsession with strategic nuclear bombing.[42] Fighting yet another unexpected war, the Air Force employed airplanes in missions for which they were not designed. As in the Korean War, "tactical" aircraft were the primary means for air interdiction and strategic attack, while in a flip-flop of roles the B-52 "strategic" bomber flew mainly close air support missions in the South. Flying out of Thailand as a fighter-bomber, the F-105 "Thunderchief" (tellingly nicknamed "Thud" by those who flew it) flew more than seventy-five percent of all strike missions against North Vietnam during ROLLING THUNDER.[43] Using its radar for guidance and a "toss bombing" computer designed for nuclear weapons, the F-105 could deliver ordnance within 1500 to 2000 feet

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[38] Tilford, *Setup*, 132; and Mrozek, *Air Power and the Ground War in Vietnam*, 99-100.
[39] Gibson, *The Perfect War*, 357-358.
[40] Benjamin S. Lambeth, *The Transformation of American Air Power* (Ithaca, NY: Cornell University Press, 2000), 31-32.
[41] Quoted in Clodfelter, *The Limits of Air Power*, 130.
[42] Weigley, *The American Way of War*, 396-397.
[43] By 1972, most of the "Thuds" had been replaced by the F-4 "Phantom." See especially A.J.C. Lavalle, ed., *The Tale of Two Bridges and The Battle for the Skies Over North Vietnam* (Washington, D.C.: U.S. Government Printing Office, 1976), 12-21.

of a target, an acceptable error in nuclear warfare, but unacceptable for conventional weapons dropped in close proximity to friendly troops or where collateral damage was a concern.[44] Since nuclear bombing required only one pass, designers and operators gave little consideration to combat survivability of the F-105, which consequently had the highest loss rate of any aircraft in Vietnam. During the war in Southeast Asia the United States lost more than half of the F-105 D and F models in the inventory.[45] The Air Force paid dearly in Vietnam, especially during the early years, for its neglect of both the technology and tactics of conventional air war.

Finding and accurately striking worthwhile ground targets was a particularly challenging problem due to the nature of the infrastructure, terrain, and weather in Southeast Asia. Unlike during the Second World War, there were no easily spotted rail yards or difficult to repair steel bridges for an effective interdiction campaign. Instead, airmen often resorted to futilely bombing terrain features like mountain passes and dirt roads with the destructive force of B-52s.[46] The predominant weather patterns of the region also limited the effectiveness of air power. Fighter-bombers were most accurate in dive-bombing roles, but this tactic required ceilings of 10,000 feet and visibility of five miles, a rare condition during the monsoon season which ran from late September through early May. In good weather, pilots were able on average to put their bombs within 400 feet of the target; low clouds and poor visibility, however, drove bombing accuracy to between 1500 and 2000 feet.[47]

[44] Thompson, *To Hanoi and Back*, 60-61.
[45] Werrell, *Chasing the Silver Bullet*, 10-15. See also Thompson, *To Hanoi and Back*, 310-312 for statistics on aircraft and aircrew losses in Southeast Asia.
[46] Tilford, *Setup*, 174-176 and 179-180.
[47] Tilford, *Setup*, 113. See also Gibson, *The Perfect War*, 358-360.

According to contemporary intelligence reports, American bombing not only hardened political will in the North, but also stimulated North Vietnam to militarily match the American escalations.[48] The ROLLING THUNDER bombing campaign stirred an increase in North Vietnamese anti-aircraft capabilities, thanks to equipment and technical advisors provided by the Soviet Union.[49] Increasingly dangerous defenses over the North and later over the Ho Chi Minh trail became "a countervailing force" that limited the achievements of American air power.[50] The Stennis Committee estimated that by the summer of 1967, North Vienamese defenses included some 200 missile sites, 7000 anti-aircraft guns, and 75-80 MiG aircraft, 15-20 of which were more capable MiG-21s.[51] Anti-aircraft guns dictated higher release altitudes and higher penetration speeds that, according to one Air Force analyst, "had an effect on accuracy that was beyond previous experience and, at that time, incalculable."[52]

After early raids into North Vietnam, Secretary McNamara complained in February 1965 that bombing had to be more accurate to effectively communicate political resolve.[53] Given the full array of countervailing forces, American air power during ROLLING THUNDER provided neither the necessary discrimination in hitting targets nor control over the course of the war expected by civilian leadership. As the commander of Air Force Systems Command noted in 1967 after nearly three years of bombing, "The offensive power of the Free World forces in Southeast Asia has been impaired by a limited ability to locate and identify the enemy... at night and in bad weather and to discriminate with enough precision to assure accurate strikes against

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[48] Cable, *Unholy Grail*, 95. Sharp, *Strategy for Defeat*, 72.
[49] Cable, *Unholy Grail*, 101-102.
[50] Appel, "Bombing Accuracy in a Combat Environment," 39.
[51] Stennis Committee report quoted in Sharp, *Strategy for Defeat*, 189.

proven military targets." Only by striking targets more accurately could the Air Force hope to fight the war more economically.[54] General Momyer, whose 7th Air Force flew most of the ROLLING THUNDER missions, later blamed "gross errors" and incidents of collateral damage on a list Clausewitzean points of friction that interfered with the conduct of the campaign: improper release of bombs at the wrong altitude, jettisoning bombs with the appearance of enemy fighters, and malfunctioning bomb racks. Having accounted for the causes of air power's failings, Momeyer nevertheless did not hold the Air Force responsible for the unintended harm, noting that damage from errant bombs in the end could not be distinguished from damage caused by North Vietnamese anti-aircraft shells and surface-to-air missiles that missed and fell back to the ground.[55]

The first step to improving bombing accuracy, and therefore its effectiveness, was to measure and account for bombing errors. Well into the ROLLING THUNDER campaign, the 7th Air Force initiated a bombing assessment program using new cameras in their fighter-bombers. The cameras were of value to commanders not just for measuring accuracy, but also for evaluating and documenting aircrew performance; the intent of the program eventually changed from analysis of accuracy to command and control. The program subsequently came to a virtual standstill, partly because of the difficulty of matching camera footage to precise target locations, but "primarily because the finger was now being pointed at the pilot." With analysts recording individual pilot

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[52] Appel, "Bombing Accuracy in a Combat Environment" 40-41.
[53] *The Pentagon Papers* (Gravel ed.), 3, 332.
[54] James Ferguson, "Tactics and Technology: The Unlimited War on Limited War," *Air University Review* 19/1 (Nov-Dec 1967), 14-17.
[55] Momyer, *Airpower in Three Wars*, 179-180. For an opposing view claiming that collateral damage was intentionally inflicted, see Gibson, *The Perfect War*, 367-377.

performance in addition to bomb performance, "the data submitted dropped to very low levels" and was generally considered "both unreliable and unacceptable."[56]

A reformed and more anonymous program functioned somewhat better, but there were still many problems with the 7th Air Force's assessment program. If a pilot was unsure about what impact point he had used for targeting, analysts made no evaluation. "Short rounds" might fall out of view of the camera. Post-release maneuvering often made observation of bomb-fall impossible, further precluding the availability of data for analysis. Aircrews still felt pressured to show performance and analysts therefore still doubted the veracity of post-flight reports. "At best, then," wrote one participant, "this measuring system was an imperfect tool." Despite its failings, the assessment program nevertheless raised important questions about the impact of avionics, training, and available weapons on bombing accuracy.[57]

One notable technological innovation to improve bombing accuracy in bad weather was the Combat Skyspot rapid-response targeting system employing mobile radars and ground controllers to guide aircraft to targets.[58] Employed primarily over South Vietnam, the new Skyspot system represented a vast improvement over the ground radar control methods of Korea, with one early report boasting that "[a]ccuracy soon surpassed that of any previously used radar synchronous bombing."[59] When the target was within range of a Skyspot radar, aircrews no longer had to depend on finding targets using aircraft radar alone, a method where bombing errors of over 3000 feet were

[56] Appel, "Bombing Accuracy in a Combat Environment," 47-48. See also "Briefing on Weapon Delivery Effectiveness Program," HQ PACAF (DOV), September 1970. AFHRA file no. K717.56-1.
[57] Appel, "Bombing Accuracy in a Combat Environment," 48-52.
[58] See Werrell, *Chasing the Silver Bullet*, 32-33; Thompson, *To Hanoi and Back*, 102-104.
[59] Quoted in William P. Head, *War from Above the Clouds: B-52 Operations During the Second Indochina War and the Effects of the Air War on Theory and Doctrine* (Maxwell AFB, AL: Air University, 2002), 28-31.

common.[60] Throughout the war, Skyspot directed 100,000 B-52 strikes and nearly 150,000 fighter strikes with an overall average error of 750 feet.[61]

This ground-based guidance system, although an improvement over earlier methods, had several important limitations. Bombers had to maintain steady course, airspeed, and altitude for about sixty miles before the bomb release point designated by the ground controller. A deviation of only one degree in course would shift the bomb's impact point by 350 feet. Aircraft flying in formation dropped their bombs simultaneously on the cue of a lead aircraft. The tighter the formation, the tighter was the bombing pattern. But closely spaced formations were a much more tempting target for the North's surface-to-air missiles. Skyspot radar covered all of South Vietnam and the southern Ho Chi Minh trail (and parts of the North from 1967 to 1968 when the Air Force established a station in Laos). In the North, however, Skyspot was not reliable and therefore of little use for precision bombing of the Hanoi-Haiphong region.[62]

Despite frustrations with the accuracy of weapons and contrary to the impressions created by widely read reports from journalists like Harrison Salisbury about the indiscriminate damage wrought across the North, there was still remarkably little collateral damage during the ROLLING THUNDER campaign.[63] By 1967, only one in 6000 sorties involved accidental bombing of friendly units or towns thanks to the use of newly introduced guidance systems, improved aircrew training, and strict command and control.[64] As the radar library of identifiable landmarks grew, so too did the accuracy of

[60] Thompson, *To Hanoi and Back*, 102.
[61] Werrell, *Chasing the Silver Bullet*, 33.
[62] Thompson, *To Hanoi and Back*, 102-104 and 225.
[63] Harrison Salisbury, "U.S. Raids Batter Two Towns; Supply Route is Little Hurt," *The New York Times*, 27 December 1966, 1. See also Thompson, *To Hanoi and Back*, 44-48.
[64] John Schlight, *The War in South Vietnam: The Years of the Offensive, 1965-1968* (Washington, D.C.: Office of Air Force History, 1988), 258-261.

radar offset bombing.[65] In 1967, General Momyer (while pleading to Secretary McNamara for a wider strategic air war) claimed that bombs were now hitting their targets with a 400 percent improvement in accuracy over the previous year thanks to new tactics and new weapons.[66]

Absent an effective strategy, however, improved accuracy and technological efficiency alone were insufficient for achieving desired outcomes. The North Vietnamese were simply willing to endure the gradually escalating pain of bombing, no matter how accurate or increasingly destructive.[67] Bombing, unable to defeat the opponent's will, was also failing to destroy North Vietnamese capabilities. In December 1967, a leading group of defense scientists concluded in the Jason Summer study that ROLLING THUNDER had not limited the North's military capacity. "As of October 1967, the U.S. Bombing of North Vietnam has had no measurable effect on Hanoi's ability to mount and support military operations in the South." North Vietnam, in fact, in response to the bombing "ha[d] made its transportation system more redundant, reduced the size and increased the number of depots and eliminated choke points."[68] Interdiction strikes compelled the North to disperse and multiply their routes to the South and extend the trail system further west in Laos and Cambodia. The Ho Chi Minh trail grew from

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[65] Thompson, *To Hanoi and Back*, 101-102. In radar offset bombing, aircrews located targets based on their "offset" (direction and distance) from a landmark easily identified by aircraft radar. The accuracy of this method depended on the accurate plotting both of prominent landmarks as well as potential targets.
[66] *The Pentagon Papers* (Gravel ed.), 4, 195-196.
[67] As the Stennis Committee noted to Congress, "The effectiveness or impact of the bombing cannot be measured alone by the number of missions flown or the number of bombs dropped. The real question is whether we are doing what we can and should do… that will end the war soonest and thus save American lives." Quoted in Sharp, *Strategy for Defeat*, 192.
[68] *The Pentagon Papers* (Gravel ed.), 4, 222-225. See also Sharp, *Strategy for Defeat*, 206-208.

820 miles of trails in 1966 to a network of 2710 miles by the fall of 1971 largely as an indirect consequence of American bombing.[69]

Although American efforts at aerial interdiction unquestionably changed logistical traffic, bombing, by encouraging the North to increase support for the insurgency in South Vietnam, swelled rather than reduced the flow of men and materials.[70] Given that the logistical requirements of the insurgency in the South were low, military supplies from the USSR, Eastern Europe and China were plentiful, and manpower was abundant, bombing could have little negative impact on the intensity of the war. According to the CIA's cost-benefit analysis of bombing, in 1965 it cost $6.60 to inflict every $1 of damage; in 1966 the ratio was 9.6 to 1. By 1967, the CIA's conclusion was that, "If economic criteria were the only consideration, NVN would show a substantial net gain from bombing, primarily in military equipment" as North Vietnamese losses were more than compensated for by shipments from its allies.[71]

COMMANDO HUNT and Aerial Interdiction

Amidst a rising crescendo of anti-war protests after the Tet Offensive, President Johnson halted the bombing of North Vietnam in October 1968. The weight of the air war quietly shifted to ground support and interdiction from the relatively benign skies of South Vietnam, Cambodia, and Laos. In a series of operations known collectively as COMMANDO HUNT, the Air Force launched ground attack aircraft to stop the flow of supplies from North to South during the dry seasons from November 1968 through

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69 Mark, *Aerial Interdiction in Three Wars*, 332-333.
70 Mrozek, *Air Power and the Ground War in Vietnam*, 103-104.
71 *The Pentagon Papers* (Gravel ed.), 4, 136 and 226. See also Gibson, *The Perfect War*, 379-382.

March 1972.[72] COMMANDO HUNT, the new focus of the air campaign, consisted both of doses of massive destruction – B-52's bombing kilometer-square boxes – and more discriminate forms of air power – newly conceived "gunships" tracking and destroying individual vehicles moving down the trail.

Aerial gunships – tactical transport aircraft like the C-47, C-119, and the C-130 armed and converted into combat aircraft – proved highly effective, especially at night both for close air support in South Vietnam and as an anti-truck weapon over Laos and Cambodia.[73] The "Cadillac" of the gunship fleet was the newly upgraded AC-130 armed with 20-mm Gatling guns and 40-mm Bofors cannons. During COMMANDO HUNT II from November 1969 to April 1970, AC-130's flew only four and a half percent of the missions, yet claimed thirty-four percent of the trucks damaged or destroyed along the Ho Chi Minh trail.[74] For COMMANDO HUNT VII from November 1971 through March 1972, AC-130's flew with low-light-level television, laser range finders, and infrared detection systems and were later armed with a computer-aimed 105-mm howitzer under the PAVE AEGIS program. Combined with increasingly refined tactics and sophisticated ground sensors, these new technologies greatly improved the gunships' already impressive capabilities for finding and destroying North Vietnamese trucks.[75]

[72] Eduard Mark, *Aerial Interdiction in Three Wars* (Washington, D.C.: Office of Air Force History, 1994), 327-364. For an econometric analysis of the COMMANDO HUNT interdiction campaigns, see Gilster, *The Air War in Southeast Asia*, 18-58.
[73] On the development of the gunship see especially the official Air Force history by Ballard, *Fixed Wing Gunships*. See also Werrell, *Chasing the Silver Bullet*, 15-23; and Mrozek, *Air Power and the Ground War in Vietnam*, 125-132. Mrozek details the difficulties the Air Force encountered whittling "the 'square peg' of the gunship through technological and tactical innovation to fill a variety of mission 'holes'."
[74] Werrell, *Chasing the Silver Bullet*, 19-20.
[75] See Bernard C. Nalty, The War Against Trucks: Aerial Interdiction in Southern Laos, 1968-1972 (Maxwell AFB, AL: Air University Press, 2005), 60-62. See also Tilford, *Setup*, 176 and 184; and Momyer, *Airpower in Three Wars*, 211-214.

The COMMANDO HUNT campaigns also gave operational experience with the emerging technology of laser guidance that would be critical to success in the 1972 LINEBACKER campaigns. McDonnell-Douglas F-4 Phantoms, the Air Force replacement for the F-105, dropped laser-guided bombs against targets designated by AC-130's, OV-10 forward air control aircraft, and even other F-4's.[76]

Slow-moving bombers, gunships, and forward air control aircraft during COMMANDO HUNT, however, proved vulnerable to enemy defenses. During the 1971-1972 campaign, the North launched more than 160 surface-to-air missiles, causing the loss of ten aircraft. By December 1971, increasingly capable ground-based defenses and more and better MiG fighters finally drove the B-52's from the skies over the trail; by the spring of 1972, enemy defenses had similarly chased away the aerial gunships.[77] "The AC-130 had been an exceptional weapon system in a semi-permissive defense environment," observed General Momeyer, "but it had to give way or become extinct when the enemy brought the full weight of his best defensive weapons against it."[78]

Compared to the complex and subjective nature of assessing the effectiveness of close air support in the South, aircrews found the effectives of interdiction much easier to quantify. In fact, the quantifiable nature of interdiction created a bias amongst gunship crews for interdiction attacks. As one contemporary Air Force historian noted, "[S]ince truck killing could be verified quite closely, the gunship crews found the usual absence of specifics from their attacks to aid troops somewhat demoralizing."[79] During COMMANDO HUNT, the number of trucks destroyed replaced sortie rates and body

[76] Momyer, *Airpower in Three Wars*, 212-213. Mark, *Aerial Interdiction in Three Wars*, 339.
[77] Mark, *Aerial Interdiction in Three Wars*, 355-356.
[78] Momyer, *Airpower in Three Wars*, 213-214.

counts as a measure of success of the air war.[80] To economic analysts and operations researchers, accumulating truck kills demonstrated increasing returns to efforts expended. By COMMANDO HUNT V, AC-130's claimed 9.72 trucks destroyed per sortie.[81]

The problem with the truck count was not that analysts were counting the wrong things, but that the statistics took on an air of objectivity and authority, when in reality they were much more subjective than portrayed. By the end of COMMANDO HUNT V, Military Assistance Command Vietnam officials estimated that air power had destroyed 16,266 trucks and damaged another 4,700. The CIA however claimed that these figures were more than twice the total number of trucks existing in all of North Vietnam and Laos.[82] Furthermore, despite Air Force counts, the trail was not littered with burnt out trucks. In tallying truck kills, crews found it extremely difficult to determine the precise effects of their attacks from the air. Although a truck might stop as bombs fell in close proximity, this did not always mean that it had been disabled, since drivers often left their trucks for shelter when aircraft attacked. There were numerous facilities along the trail to fix damaged vehicles; trucks were therefore only truly unusable if they blew up or burned.[83] To frustrate the American count, the North actively used decoys and employed deceptive measures like creating secondary explosions around intact vehicles.[84] Testing at Tan Son Nuht Air Base in Thailand and at Hurlburt Field in

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[79] Jack S. Ballard, *Development and Deployment of Fixed-Wing Gunships,1962-1972* (Washington, D.C.: Office of Air Force History, 1972), 249; Mrozek, *Air Power and the Ground War in Vietnam*, 131.
[80] See especially Henry Zeybel, "Truck Count," *Air University Review* 34/2 (Jan-Feb 1983), 36-45. See also Barry Watts, "Review of Earl Tilford Crosswinds: The Air Force's Setup in Vietnam," *Air Power History* (Winter 1993), 56. On the continuing relevance of body counts, see Bradley Graham, "Enemy Body Counts Revived: U.S. is Citing Tolls to Show Success in Iraq," *The Washington Post* (24 October 2005), A1.
[81] See Gilster, *The Air War in Southeast Asia*, 42-46. Momyer, *Airpower in Three Wars*, 212.
[82] Head, *War from Above the Clouds*, 53. Tilford, *Setup*, 182-185.
[83] Mark, *Aerial Interdiction in Three Wars*, 358-363. Head, *War from Above the Clouds*, 53-55.
[84] Gibson, *The Perfect War*, 398-399.

Florida further demonstrated just how difficult it was to disable a truck and to correctly measure the extent of damage.[85]

Even if the truck count were more exact, it was only a quantified measure of tactical success that masked the strategic failures of the campaign. The halt to ROLLING THUNDER in 1968 ended the synergistic effects of simultaneous interdiction and strategic campaigns. Interdiction had little chance of success as the absence of bombing in the North allowed trucks (that were difficult to stop thereafter) a head start down the trail.[86] The clearest indication of the failure of the aerial interdiction campaign despite the growing tally of destroyed trucks was that the North could clandestinely deploy some 200 tanks (theoretically much easier to detect than trucks) along the border with the South for its Easter Offensive in the spring of 1972.[87]

The Emergence of True Precision

The most important advances in the search for improved accuracy during the Vietnam War involved electro-optical and laser guidance. The U.S. Navy had not been as negligent of conventional precision as the nuclear-focused Air Force. As with bombsights in the 1920's and 1930's, the Air Force therefore turned to the Navy for its bombing technology. The Navy's AGM-62 Walleye was an electro-optically guided launch-and-leave glide bomb that combined a television camera and computer with an 850-pound warhead.[88] The Navy first employed Walleye television-guided bombs in

[85] Mrozek, *Air Power and the Ground War in Vietnam*, 131. In Mrozek's words, "The meaning of the "truck count" remains clouded, a disturbing side effect of the passion to quantify military performance."
[86] Mark, *Aerial Interdiction in Three Wars*, 358-360.
[87] Mark, *Aerial Interdiction in Three Wars*, 363. Sharp, *Strategy for Defeat*, 243.
[88] On the early development and deployment of electro-optically guided bombs in Vietnam see Melvin F. Porter, *Second Generation Weaponary* (sic) *in SEA*, HQ PACAF, CHECO Division (10 September 1970), 3-17. AFHRA file no. K717.0413 80. See also Donald I. Blackwelder, *The Long Road to Desert Storm*

March 1967 against buildings, bridges, and power plants, scoring sixty-eight hits out of seventy-one bombs dropped.[89] The 8th Tactical Fighter Wing (TFW) of the Air Force at Ubon Royal Thai Air Base in Thailand received its first Walleyes in August 1967. Of the twenty-two Walleyes the 8th TFW dropped in 1967, mainly against bridges, thirteen hit their targets, two were near misses, and only seven missed entirely.

As with other embryonic technologies, there were limits to the Walleye's capabilities. The relatively unsophisticated optical guidance system was only good in bright sunlight against high contrast targets; late morning or early afternoon when sun angles gave the best sharp shadows and stark contrasts was the best time for Walleye missions. The Walleye's television guidance system was easily fooled by camouflage or diverted by the interposition of clouds, dust, or smoke. The weapon also required a long, stable approach for target acquisition and lock-on. The Air Force halted the program to assess its effectiveness in November 1967, but use of the Walleye resumed after January 1968 against targets in North Vietnam and then against interdiction targets and caves after the ROLLING THUNDER bombing halt in October. The Navy developed an improved version of the Walleye with a larger warhead, the AGM-62 Walleye II in January 1969. The Air Force also introduced its own modular electro-optical guided kit for the 2000 pound bomb PAVEWAY II, also known as HOBO (HOming BOmb), in February 1969. But even with these improvements, electro-optically guided bombs accounted for only six percent (four percent Walleyes and two percent HOBOs) of all

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and Beyond: The Development of Precision Guided Bombs (Maxwell AFB, AL: School of Advanced Airpower Studies, May 1992), 28-30; and Paul G. Gillespie, *Precision Guided Munitions: Constructing a Bomb More Potent Than the A-Bomb,* unpublished dissertation (Lehigh University, June 2002), 153-158.
[89] Lavalle, *The Tale of Two Bridges*, 67-69.

guided bombs used in Vietnam due to their operating limitations and higher costs.[90] By late 1969, the Air Force was flying Walleye missions at a frequency of only around four per month.[91]

Work with laser guidance first began at the U.S. Army Missile Command, Redstone Arsenal in 1962 for use in anti-tank weaponry. The Army, realizing that Vietnam would not be a tank war, cut funding for the project, which was subsequently adopted by the Air Force in 1965 and redesignated Project PAVEWAY in 1967.[92] The first prototype air to ground weapons with laser guidance arrived at the 8th TFW in 1968. F-4s from the 8th TFW operationally tested the new weapon in the relatively safer skies over southern North Vietnam from May through August 1968.[93]

Unlike the Walleye in which the guidance system was integrated within the munition, the PAVEWAY I had a modular guidance kit with a laser-seeking head, a small computer, a special tail assembly and small control surfaces that were attached in the field to a conventional 2000 or 3000-pound bomb. The delivery aircraft released the bomb into a "basket" defined by the field of view of the laser sensor and the maneuverability of the bomb.[94] Once the seeker mechanism detected the reflected energy of the laser beam, the computer directed the control surfaces to guide the bomb to target. Either the attacking aircraft or a different aircraft could laser designate the target; one aircraft could designate for many bomb droppers and multiple bombs could home in on

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[90] Werrell, *Chasing the Silver Bullet*, 144.
[91] Porter, *Second Generation Weapon(ry) in SEA*, 11-17.
[92] Blackwelder, *The Long Road to Desert Storm*, 22-28; Gillespie, *Precision Guided Munitions*, 158-168.
[93] On early research and development of laser-guided munitions, see Peter deLeon, *The Laser-Guided Bomb: Case History of a Development*, RAND Report R-1312-1-PR, June 1974. On the operation and early deployment of LGBs in Vietnam, see Porter, *Second Generation Weapon(ry) in SEA*, 18-48. See also Werrell, *Chasing the Silver Bullet*, 147-163.
[94] Porter, *Second Generation Weapon(ry) in SEA*, 20.

the same laser. A bomb that lost the laser or "broke lock" because of intervening clouds or haze would fall the remaining distance like a conventional ballistic bomb.

Laser-guided bombs held several advantages over electro-optically guided bombs. The most significant advantage was the $3400 price tag, compared to $16,000 for the mini-television camera kit of the electro-optical bomb.[95] Laser-guided bombs could also be dropped from a much higher altitude (10-14,000 feet versus 6000 feet) and were therefore safer than television-guided bombs.[96] One early computer simulation analyzing the advantages of laser-guided bombs estimated that they would be 200 times more efficient than conventional unguided bombs at destroying targets.[97] True to these predictions, of the first 1612 laser-guided bombs dropped in calendar year 1969, 1349 effectively guided, 1114 caused damage to their targets, and 923 scored direct hits.[98] During 1969, the eighty-five percent of bombs that guided achieved an average error less than the lethal radius of the bomb.[99]

But as with electro-optically guided bombs, laser-guided bombs had certain operational shortcomings. Laser designators had to be able to see the target for it to be attacked. Weather, therefore, was a constraining factor – intervening clouds and haze would cause the bomb to break lock and miss the target.[100] Previous strikes frequently raised dust and smoke that threw off subsequent laser guidance, making large strike elements or repeated strikes unworkable. Laser designating a target required the

[95] Tilford, *Setup*, 246.
[96] Head, *War from Above the Clouds*, 66 and 69.
[97] Peter deLeon, *The Laser-Guided Bomb: Case History of a Development*, RAND Report R-1312-1-PR (June 1974), 1.
[98] "Guided Bombs – Problems of Utility and Cost," Operations Analysis Headquarters, USAF, February 1971, 12. AFHRA file no. K143.504-32.
[99] Werrell, *Chasing the Silver Bullet*, 149.

illuminator to circle in a vulnerable 30-degree bank turn while the rest of the flight delivered their ordnance, an untenable maneuver in the face of strong defenses. Laser-guided bombs were not a fire-and-forget weapon as at least one aircraft had to stay to continuously laser designate the target until impact. Several laser designators operating against different targets within a small area might also result in misdirection of bomb guidance or bombs clustering on the same target. The accuracy and therefore the effectiveness of laser-guided munitions was contingent on the context of their employment.[101]

Another precision technology originally developed by the Army Air Forces during World War II but subsequently sidelined by the Cold War Air Force was the anti-radiation missile that homed in on enemy radar emissions. The AGM-45 SHRIKE anti-radiation missile was first operationally employed by the Navy in 1963 but later fired first by an Air Force F-100 in April 1966 and then by an F-105 in April 1968. The SHRIKE had a standoff range of ten to twelve nautical miles, but only a 51-pound warhead that was rarely effective at destroying radar complexes. The addition of white phosphorous, however, did at least reveal the position of targeted radars for subsequent strikes.[102]

Enemy radar operators quickly adapted to the SHRIKE by turning off radars when detecting a missile launch. Kill rates fell from twenty-eight percent in 1966 to eighteen percent in the first quarter of 1967.[103] Although this tactic foiled the missile, it was also self-defeating since anti-aircraft defenses were less effective without radar guidance. The

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[100] See especially Patrick J. Breitling, "Guided Bomb Operations in SEA: The Weather Dimension, 1 Feb – 31 Dec 1972," HQ PACAF, CHECO/Corona Harvest Division, 1 October 1973. AFHRA file no. K717.0414-43.
[101] Werrell, *Chasing the Silver Bullet*, 137.
[102] Porter, *Second Generation Weapon(ry)*, 59-70; Gillespie, *Precision Guided Munitions*, 152-153; and Thompson, *To Hanoi and Back*, 36-37.
[103] Werrell, *Chasing the Silver Bullet*, 50.

AGM-78 anti-radiation missile, a larger version of the SHRIKE developed by the Navy, had a 75-mile standoff capability and a memory circuit to keep the missile heading toward the target even after the radar was shut down. This version, however, was ten times more expensive and less mechanically reliable than the original SHRIKE. Greater standoff range also complicated employment since Navy ships and Army radar sights also used the S-band radar targeted by the missile. Pilots therefore could only fire the missile from shorter distances after visually identifying the target to discriminate between friendly and enemy "emitters."[104] Despite these issues, the anti-radiation missile became an increasingly important part of the air-to-ground arsenal as the threat from enemy anti-aircraft defenses steadily increased after 1969.

LINEBACKER I and II

After October 1968, bombing in North Vietnam was limited to "protective reaction" strikes, where fighters escorting reconnaissance missions attacked active defense installations.[105] High-value point targets were few and the Air Force and Navy employed guided weapons primarily for interdiction and defense suppression. With the lifting of bombing restrictions after the North Vietnamese Easter Offensive in March 1972, however, the new "smart" bombs were suddenly in high demand. In fact, the Pacific Air Forces ordered that guided weapons were to be used whenever possible in disrupting the North's offensive.[106] The LINEBACKER campaigns were thus the first modern air campaigns centered on effective precision-guided munitions.

[104] Thompson, *To Hanoi and Back*, 105.
[105] Momyer, *Air Power in Three Wars*, 30-31.
[106] Mark, *Aerial Interdiction in Three Wars*, 381.

The advantage of the new and more effective precision-guided weapons was two-fold. First, because the weapons were more accurate, air power could now hit targets previously off limits for fear of collateral damage. By greatly reducing the risk to surrounding structures, guided weapons allowed strikes against smaller petroleum pumping and storage areas, military repair shops, and North Vietnamese air control centers located near villages or in city neighborhoods.[107] Precision weapons were particularly useful for destroying bridges and tunnels between Hanoi and the Chinese border and power generating facilities previously forbidden for fear of damaging nearby dams and dikes. Second, air power armed with precision-guided weapons could destroy designated targets using fewer sorties. "With fewer strike aircraft required to assure target destruction," one Air Force officer deduced after the war, "more targets could be attacked and a larger number of aircraft assigned to defending the strike force."[108] For operators and analysts looking for the maximum return for their efforts, precision-guided munitions promised efficiency in striking and destroying targets without unduly endangering either enemy civilians or large numbers of friendly aircraft and aircrews.[109]

The new found accuracy of precision weaponry combined with the determination of the Nixon administration and the atmosphere of détente resulted in the lifting of many of the previous restrictions on bombing in the North. Air power, however, was not totally unfettered and political objectives still dictated acceptable targets and the ways in which these targets could be struck. Like ROLLING THUNDER, the objective of the LINEBACKER operations was not to destroy the North Vietnamese regime, but rather to

[107] Porter, *LINEBACKER: Overview of the First 120 Days*, 31; Tilford, *Setup*, 235-237 and 246-247. For a contemporary account of the utility of guided weapons, see "U.S. Guided Bombs Alter Viet Air War," *Aviation Week and Space Technology* (22 May 1972), 16-17.
[108] Lavalle, *The Tale of Two Bridges*, 92.

end the North's offensive against the South and bring the war to a negotiated settlement.[110] Many targets, like the main power plant in downtown Hanoi, the port area of Haiphong, and sites along the Chinese border, remained off limits to air power because of the possibilities of collateral damage and civilian casualties, even with the new guided weaponry. Dikes and dams, targets considered decisive in Korea, also remained on the prohibited list. Direct attack against North Vietnamese leadership, as in ROLLING THUNDER, was also prohibited. Although less restrained than ROLLING THUNDER, the LINEBACKER campaigns were nevertheless subject to political limits, especially given the growing importance of unfavorable public opinion about American actions.[111]

Fearing that misplaced bombs might put important targets off limits, Air Force leaders turned to the discrimination of smaller fighter-bombers for targets in the North, much as they had in both World War II and Korea.[112] The two most notable tactical aircraft of the campaign were the McDonnell-Douglass F-4 "Phantom II," the most versatile fighter of the war, and the General Dynamics F-111 "Aardvark," the ultimate in the American trend toward "technowar." The F-4 was the first jet fighter fathered by the Navy to be adopted by the Air Force. The F-4E with improved air-to-ground capabilities played a primary role during LINEBACKER, not only in dropping bridges and cratering roads in front of the advancing offensive in the South, but also in precisely striking difficult targets in the North.[113] Since all laser illuminators were located at Ubon in Thailand, the 8th TFW's F-4's from Ubon were given responsibility for the delivery of

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[109] Mrozek, *Air Power and the Ground War in Vietnam*, 102.
[110] See especially W. Hays Parks, "Linebacker and the Law of War," *Air University Review* 34/2 (Jan-Feb 1983), 2-30.
[111] On the differences in targeting between ROLLING THUNDER and LINEBACKER I and II, see especially Vogt interview, 52-54; and Parks, "Linebacker and the Law of War."
[112] Thompson, *To Hanoi and Back*, 226.
[113] Lavalle, *The Tale of Two Bridges*, 21-23. Tilford, *Setup*, 226.

laser-guided ordnance during LINEBACKER. B-52's were well known for their massive effects, but it was the F-4 that was the workhorse in the North delivering precision weapons against strategic targets.

The F-111 was significant because of its all-weather capabilities and its ability to penetrate and bomb without the large support packages required by other aircraft like the B-52.[114] F-111 crews used terrain-following radar to fly below enemy defenses at high airspeeds and then bomb targets based on offsets from terrain features easily distinguishable on radar. Because it did not yet have a laser target designator to deliver guided weapons, the F-111 was better suited for area targets and for periods of bad weather or at night. Three of the first six F-111 aircraft introduced to the theater in March 1968 crashed, ending their combat deployment after only a month. Although there were still growing pains after the airplane's reintroduction in September 1972, the F-111 flew some 1500 sorties during LINEBACKER I at the cost of four aircraft.[115] F-111's achieved initial accuracies of around 600-900 feet off target using conventional bombs and radar offset methods; by the time of LINEBACKER II in December, their average error had improved to less than 300 feet.[116]

Because of the smaller number of aircraft available and the use of precision-guided weapons, the tonnage of bombs that fighters dropped on the North in 1972 was much less than in the earlier ROLLING THUNDER campaign.[117] The development of

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[114] See especially "The F-111 in Southeast Asia, September 1972-January 1973," HQ PACAF, CHECO/Corona Harvest Division, n.d. AFHRA file no. K717.0414-44. See also Werrell, *Chasing the Silver Bullet*, 23-31; Futrell, *Ideas, Concepts, Doctrine*, 2, 479-482; and Maj. Gen. Eugene L. Hudson, End of Tour Report, 1 May 1973, 17-18. AFHRA file no. K740.131.
[115] Thompson, *To Hanoi and Back*, 101 and 245-247.
[116] Werrell, *Chasing the Silver Bullet*, 30.
[117] Thompson, *To Hanoi and Back*, 301. Precision weapons played a key role not only in the preferred "strategic" campaign in the North, but also in providing close air support to stop the conventional offensive

guided bombs has been closely associated with the destruction of bridges ever since World War II. The disproportional benefits of the latest versions of guided weapons in Vietnam are perhaps best (and most frequently) told through a piece of Air Force lore known as the "Tale of Two Bridges."[118] The first of the two bridges was the massive structure at Than Hoa. Located some 10 kilometers from the Gulf of Tonkin in the southern panhandle of North Vietnam, the bridge the Vietnamese knew as "the Dragon's Jaw" was 540 feet long and 56 feet wide and had two steel thru-truss spans that rested in the center on a massive reinforced concrete pier. Between 1965 and 1972, the North Vietnamese further reinforced the structure to withstand American bombing by adding eight additional concrete piers near the approaches to the bridge.[119]

As frustrated pilots later acknowledged, this relatively "unengineered" bridge that "had, architecturally, been grossly overbuilt" greatly benefited from its structural inefficiency. The first strikes against the Than Hoa bridge were in April 1965 by F-105's armed with AGM-12 "Bullpup" missiles, a 250-pound electro-optically guided missile developed by the Navy. This mission scored several hits but failed to inflict permanent damage on the bridge. "[I]t became all too obvious that firing Bullpups at the Dragon was about as effective as firing B-B pellets at a Sherman tank."[120] Even unguided 750-pound bombs that scored hits and later "Big Bullpups" with 1000-pound warheads could not bring down the massive structure. On 12 March 1967, the Navy dropped three Walleyes that again hit the bridge but failed to destroy it.[121]

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in the South. About half of the laser-guided bombs dropped in 1972 were used against targets in South Vietnam and Laos, most notably against artillery and tanks. *Ibid.*, 252.

[118] Thompson, *To Hanoi and Back*, 233-236.

[119] Lavalle, *The Tale of Two Bridges*, 9.

[120] Lavalle, *The Tale of Two Bridges*, 31-44.

[121] Lavalle, *The Tale of Two Bridges*, 67-69.

With the improved munitions of LINEBACKER I, however, air power no longer just "cratered the approaches" to the bridges (a euphemism for failing to destroy them).[122] On 13 May 1972, three flights of four F-4's carrying laser-guided bombs and one flight armed with conventional bombs attacked the Dragon. The carefully placed bombs knocked the western span of the bridge completely off its forty-foot thick concrete abutment and critically disfigured the remaining superstructure. As an official Air Force evaluation later reported, "In one day, 15 guided [1000-pound] MK-84s, nine laser guided M-1118s (a 3,000 pound demolition bomb), and 48 MK-82 500-pound bombs accomplished what could not be done in three previous years."[123]

The second bridge was the Paul Doumer Bridge, 5532 feet in length and 38 feet wide, across the Red River just north of downtown Hanoi. The bridge was an especially difficult target due to its narrow width and the fact that it sat in the middle of a number of villages and small towns. For several years during ROLLING THUNDER, President Johnson had prohibited attacks on the bridge because of its proximity to Hanoi. During the first raids against the bridge in August 1967, F-4's and F-105's armed with conventional 3000-pound bombs managed to bring down a single span of the bridge.[124] The damage was only temporary, however, and the bridge was back up and running by October when another raid closed the bridge for a month. In December, a massive raid by fifty F-105s armed with two 3000-pound bombs apiece felled seven of nineteen spans. Despite the extent of the damage, however, the bridge was once again carrying railroad traffic three months later.

[122] Charles Mohr, "Bombing of North Termed Highly Effective by the United States," *The New York Times* (24 May 1972), 1.
[123] "Linebacker: Overview of the First 120 Days," HQ PACAF, CHECO/Corona Harvest Division, 27 September 1973, 24. AFHRA file no. K717.0414-42.

On 10 May 1972, sixteen F-4's dropped twenty-two laser-guided and seven electro-optically guided 2000-pound bombs on the Paul Doumer Bridge. The first flight attacked with the electro-optically guided bombs and missed the bridge entirely, souring the 8th TFW on the use of television-guided bombs. The next three flights hit the bridge with their laser-guided bombs, rendering it temporarily unusable, but failed to destroy any steel spans of the bridge. On the very next day, a single flight of four F-4's returned with two 3000-pound laser-guided bombs and six more 2000-pound laser-guided bombs. Three spans broke away from the bridge, permanently disabling it for the rest of the war.

The lesson of the raids on the two bridges was not just that precision weapons could achieve significant effects, but more importantly, that size does matter. Early failures to permanently disable the massive bridges were due not only to the difficulty of hitting the target, but also because the bomb was too small for the job. As one analyst concluded, "if a target was worth assigning a guided bomb – with its expensive seeker head, guidance and control equipment – then cost effectiveness alone dictated that it be mated to a heavier, all-purpose and more accurate bomb."[125] Just hitting the target was not enough; the explosive power delivered had to be matched to the task at hand.

Between 6 April and 30 June 1972, F-4's of the 8th TFW destroyed a total of 106 bridges with guided bombs.[126] The precision bombing campaign then turned to petroleum storage facilities, power-generating plants, and "military barracks and headquarters" (another military euphemism for buildings attacked in the absence of other high-value targets). In one particularly noteworthy attack in June, F-4's using laser-guided bombs destroyed all three generators at the new Lang Chi hydroelectric plant on

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[124] Lavalle, *The Tale of Two Bridges*, 67-77.
[125] Porter, *Second Generation Weapon(ry) in SEA*, 23.

the Red River northwest of Hanoi, a target President Nixon only reluctantly approved due to its proximity to a large earthen dam, while leaving the adjacent spillway and dam intact.[127] Despite pilot preferences for laser-guided bombs, electro-optically guided bombs were responsible for a large number of successful strikes. Of the 500 electro-optically guided bombs dropped between April and October 1972, eighty percent effectively guided with fifty-two percent achieving direct hits.[128] A July 1972 operations analysis highlighted the differences between ROLLING THUNDER and LINEBACKER I, estimating that precision-guided munitions made bombing nearly five times as effective at destroying bridges, ten times at disabling air defense sites, and two to three times more effective at destroying or damaging tanks, trucks, and lines of communication.[129]

Weather, however, remained a limiting factor. "The bastards have never been bombed like they're going to be bombed this time," Nixon had declared, "but you have to have weather."[130] The North Vietnamese timed the Easter Offensive with the end of the rainy season when clouds and rain kept most of the jet fighters and bombers grounded in Thailand. The weather respite allowed time for friendly and enemy units to intermingle, complicating the application of air power in support of ground forces in the South.[131] When aircraft managed to launch in marginal weather, clouds and overcast diffused laser beams and lessened the sharp contrasts needed to aim electro-optically guided bombs effectively. The difficulties of forecasting weather over the North, even twenty-four hours in advance, complicated ordnance selection, although the availability of satellite

[126] Lavalle, *The Tale of Two Bridges*, 83-92.
[127] Thompson, *To Hanoi and Back*, 251. It had been estimated that as many as 23,000 civilians would die if the dam were breached. Parks, "Linebacker and the Law of War."
[128] Blackwelder, *The Long Road to Desert Storm*, 30.
[129] Walter F. Lynch, "LGB Sortie Effectiveness," Operations Analysis Office, HQ Pacific Air Forces, 21 July 1972. AFHRA file no. K717.56-2
[130] Quoted in Thompson, *To Hanoi and Back*, 220; and Summers, *On Strategy*, 185.

imagery made the problem somewhat easier than it had been in Korea. Because weather often precluded the use of precision-guided munitions, planners at PACAF had to use eight to sixteen unguided sorties daily to meet the forty-eight sortie per day minimum directed by "higher headquarters."[132]

The weather also interacted with and strengthened the North's much-improved network of air defenses. Pilots maneuvering in poor weather had less time to visually sight and successfully evade approaching surface-to-air missiles. Cloud layers and surface-to-air missiles forced attacking aircraft to fly at lower altitudes where anti-aircraft guns were more effective, especially over high value targets like the Than Hoa and Paul Doumer bridges, which were not hit until more than a month into the campaign.

The best alternative when meteorological conditions did not allow bombing with guided weapons was the use LORAN (LOng Range Air Navigation radar) supplemented by aircraft radar, especially over areas where Skyspot ground-based radar was not available. Similar to SHORAN used during the Korean War, LORAN used ground radar stations to triangulate the position of aircraft equipped with LORAN receivers. The accuracy of the system, however, depended on the accuracy of target coordinates – existing maps of North Vietnam were insufficient for precise LORAN strikes. With the monsoon season approaching in August, threatening weather that would rule out the extensive use of guided bombs, the Air Force put great effort into refining target coordinates to improve existing LORAN capabilities.[133] During Operation COMBAT

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[131] Tilford, *Setup*, 225.
[132] "History of Linebacker Operations, 10 May 1972-23 October 1972," Headquarters, 7th Air Force, n.d., 25-28. AFHRA file no. K740.04-24.
[133] "Linebacker: Overview of the First 120 Days," HQ PACAF, CHECO/Corona Harvest Division, 27 September 1973, 51-52. AFHRA file no. K717.0414-42. Thompson, *To Hanoi and Back*, 246-247.

THUNDER, aircrews carefully photographed every LORAN target before and after strikes to further refine exact coordinates.[134]

Even with these improvements, conventional LORAN missions were much less accurate than either guided weapons or "dumb" bombs dropped in visual meteorological conditions and therefore accounted for a smaller percentage of target damage. Airplanes using LORAN for bombing usually missed either long or short, so aircrews had to carefully map the approaches to targets to avoid potential collateral damage. Causes of inaccuracy included signal degradation (the master station in Thailand was over 600 miles from Hanoi) that caused the system to loose lock during maneuvering, interference from thunderstorms, and aircraft maneuvering to avoid surface-to-air missiles. Even with LORAN, weather criteria for mission launch were still 8000 feet above clouds and 3000 feet below an overcast to give adequate time for visual acquisition and avoidance of surface-to-air missiles. The practical service ceiling for the bomb-laden F-4, however, was around 20,000 feet, which meant the tops of clouds could be no more than 10-14,000 feet.[135]

Although statistics on the accuracy and destructiveness of precision-guided munitions during the campaign are important, a more valid measure of their effectiveness is their impact on the enemy and the reactions and adaptations precision bombing provoked. The North Vietnamese immediately recognized the qualitative difference in the new bombing campaign, noting in their official air force history "the more

[134] Maj. Gen. Eugene L. Hudson, End of Tour Report, 1 May 1973, 17. AFHRA file no. K740.131. See also "History of Linebacker Operations, 10 May 1972-23 October 1972," 55-56.
[135] "History of Linebacker Operations, 10 May 1972-23 October 1972," 55-58.

sophisticated and much more effective" weapons the Americans were using.[136] The North Vietnamese also quickly detected patterns and vulnerabilities in American precision weapons. In one attack on 10 June 1972, a Walleye penetrated a power plant but failed to explode. The North Vietnamese took full advantage, dispatching "engineer and military scientific cadre to the scene to study the bomb's operating principles and the tactics and technology used by the enemy in order to develop counter-measures."[137] These countermeasures included painting power plant facilities and surrounding areas in Hanoi black and further camouflaging other key targets to reduce the contrast needed by optically guided bombs. To spoof both optically and laser-guided munitions, the North Vietnamese used smudge pots and other smoke generators to put up screens around critical targets when American aircraft approached.[138] Although of limited effectiveness, these passive measures nevertheless complicated the American targeting problem.

The North Vietnamese also improved their active defenses, resulting in greater losses of American aircraft and less efficient and effective strike sorties. Defenses were greater than the simple sum of their parts. Aircraft flying at low altitudes to avoid the more robust network of surface-to-air missiles were more vulnerable to anti-aircraft guns and small arms fire, which all total accounted for sixty-six percent of aircraft losses over

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[136] Official North Vietnamese Air Force history of the war quoted in Merle Pribbenow, "The North Vietnamese View of the Rolling Thunder and Linebacker Campaigns," unpublished paper, 11.

[137] *History of the Air Defense Service*, Vol. II (Hanoi: People's Army Publishing House, 1993), 145-146. This section translated by Merle Pribbenow.

[138] *History of the Air Defense Service*, Vol II, 164 and 197; and *History of the Air Defense Service*, Vol. III (Hanoi: People's Army Publishing House, 1994), 114-116. The development of countermeasures against American precision munitions began during the interdiction campaigns in Laos after 1968. "Our work directed against television-guided bombs (Walleye) and Laser Guided Bombs (LGB) marked a great step forward in the scientific and industrial maturation of our armed forces.... Based on both documents obtained from the public media as well as actual on-site studies, we were able to confirm that the enemy was using LGBs [laser-guided bombs] on the Ho Chi Minh Trail and had already conducted research into counter-measures, such as use of smoke screens, before the enemy began using this type of bomb against North Vietnam." *Industrial Characteristics of Weapons and Equipment Technology of the People's Armed*

the North.[139] Although only four percent of all aircraft losses were due to aerial combat, the enemy air threat was nevertheless not insignificant.[140] By 1972, North Vietnam had as many as 250 MiGs, improved jet-capable airfields, and upgraded radar guidance and control facilities.[141]

The quantitative and qualitative improvements in defenses necessitated the "complexification" of the American air effort. Strike packages became increasingly sophisticated, more costly, and less efficient as a much smaller portion of aircraft were dedicated to the actual delivery of munitions.[142] In a typical LINEBACKER mission, it took some forty-eight "Wild Weasel," chaff bomber, chaff escort, strike escort, and MiG-cap aircraft to get a dozen aircraft armed with precision munitions over a target.[143] Additionally, these increasingly complex and costly strike packages required other supporting assets like reconnaissance aircraft, tankers, and search and rescue missions. This increase in operational complexity was a reaction both to enemy adaptations as well as to the value of the new weaponry. When coupled with the constantly changing operational and political context, the added complexity subtracted from the overall efficiency the new technologies brought to the air war.[144]

One typical example of efforts to simplify the increasing complexity of air operations was the introduction of the PAVE KNIFE system. PAVE KNIFE was a wing-

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Forces of Vietnam During the Many Phases of the Revolution (Hanoi: People's Army Publishing House, 1994), 122. These selections translated by Merle Pribbenow.

[139] Kenneth P. Werrell, "Linebacker II: The Decisive Use of Air Power?" *Air University Review* 38/2 (Jan-Mar 1982).

[140] Throughout the war, the USAF lost 1,443 aircraft to ground fire, 110 to surface-to-air missiles, 67 to aerial combat, 96 to ground attack on air bases, and 21 from unknown causes. Thompson, To *Hanoi and Back*, 311.

[141] Werrell, *Chasing the Silver Bullet*, 47.

[142] Futrell, *Ideas, Concepts, and Doctrine*, 2, 296-297. Mrozek, *Air Power and the Ground War in Vietnam*, 106. Lavalle, *The Tale of Two Bridges*, 24-28.

[143] Lambeth, *The Transformation of American Air Power*, 51, n. 108.

mounted laser designation pod that allowed an F-4 crew to both designate a target and deliver a laser-guided munition. With PAVE KNIFE all members of a flight could drop bombs, whereas before the lead aircraft could illuminate but not drop. Because the new device decreased overall exposure time and increased effectiveness, the Air Force used PAVE KNIFE in higher threat areas whenever possible. Unfortunately, there were only four operational PAVE KNIFE laser designating pods available for all of the LINEBACKER operation.[145] Because these assets were so scarce, commanders had to deploy additional aircraft to escort and protect them in high threat areas.[146] The use of the valuable pods, intended to simplify strike packages, in fact increased the number of aircraft required.

Precision guided munitions were important in the success of LINEBACKER I, but perhaps not as decisive as they have been portrayed. Although precision-guided munitions were remarkably effective against structural features like bridges and industrial targets, the North was not totally dependent on such things. The North compensated for what it lost through adaptation and substitution. North Vietnam substituted outside aid from China and the Soviet Union for missing sources of supply, converted to highly dispersed and decentralized methods of handling supplies, constructed miles of highway bypasses, and quickly restored or went around destroyed bridges.[147] Waterways and pipelines, more difficult targets to affect from the air, replaced damaged road and rail

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[144] Mrozek, *Air Power and the Ground War in Vietnam*, 171-175. Ballard, *Fixed-Wing Gunships*, 256.
[145] Vogt interview, 136-137. Thompson, *To Hanoi and Back*, 231.
[146] "The USAF in Southeast Asia, 1970-1973: Lessons Learned and Recommendations," HQ PACAF, Corona Harvest, n.d., 86-87. AFHRA file no. K717.0423-11.
[147] Mark, *Aerial Interdiction in Three Wars*, 399 and 408-409. Mark contends that the critical shortfall in the American war effort was the ability to carry out extensive armed reconnaissance north of the southern panhandle of North Vietnam to interdict the stream of supplies flowing from China to the South. Given the shrunken size of American tactical aviation, the United States could not afford even the modest attrition rates that North Vietnamese defenses might inflict on such an effort.

routes.[148] LINEBACKER I, in effect (as the formal Air Force bomb survey concluded) hardened the North Vietnamese system to the more intense attacks of LINEBACKER II. "The LINEBACKER II campaign would have been more effectively waged prior to LINEBACKER I when the rail centered transportation network offered very lucrative supply concentrations instead of the dispersed, truck-oriented system actually found during LINEBACKER II.[149] As in World War II and Korea, substitution and repair negated the positive effectiveness of precision bombing over the course of the campaign.[150]

The effectiveness of the new technology, then, was contingent not only on a valid strategy, a strategy that matched political objectives to the target set at hand, but also on the context in which guided weapons were employed and the reactions and adaptations of a coevolving enemy. Still technologically emergent, smart weapons faced many limitations, the most important being the weather. LINEBACKER II, launched during the middle of the rainy season in December, saw even greater constraints on the use of precision-guided weapons than during LINEBACKER I.

LINEBACKER II, the eleven-day aerial offensive against North Vietnam from 18 to 29 December 1972, is known for its intensity and the absence of restraint. The Nixon administration saw air power as a means for demonstrating the United States' determination, but there were nevertheless continuing requirements for discrimination. Concerns about collateral damage were foremost in the minds of policy makers since indiscriminate raids might disrupt détente or encourage the Chinese and Soviets to come

[148] Mark, *Aerial Interdiction in Three Wars*, 334-335.
[149] "Linebacker II: USAF Bombing Survey," HQ Pacific Air Forces, April 1973, 6. AFHRA file no. K717.64-8.
[150] Gilster, *The Air War Over Southeast Asia*, 117-136.

to the aid of the North. The administration still sought to avoid unnecessary civilian casualties. As Nixon warned the Commander of SAC, General John C. Meyer, "I want the people of Hanoi to hear the bombs... but minimize damage to the civilian populace."[151] Reflecting these concerns, B-52 target maps included the locations of civilian facilities and POW camps, and briefers instructed aircrews to return with their bombs if there was any doubt about their ability to precisely hit their intended targets.[152] Precision-guided bombs, then, despite the potential of mass bombing for driving the North back to the bargaining table, were still the preferred weapon.

The overcast weather associated with the northeast monsoon, however, prevented the extensive use of precision-guided weapons during LINEBACKER II.[153] Throughout the entire period, there were less than twelve hours of weather good enough for visual bombing or the use of laser or optically guided weapons.[154] Instead, planners picked targets suitable for all-weather airplanes like the F-111, the B-52, the Navy's A-6, or LORAN directed fighter-bombers dropping unguided munitions. Targets lists as a result consisted primarily of what were essentially area targets – railway marshalling yards, airfields, and warehouses – and critical point targets were reserved for those few hours of satisfactory weather.[155] Of all bombs dropped on the North during LINEBACKER II, only .2 percent of bombs were laser-guided. The rest were "dumb" bombs dropped either visually or using LORAN or radar guidance.[156]

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151 Nixon quoted in Head, *War from Above the Clouds*, 76.
152 Clodfelter, *The Limits of Air Power*, 190-191.
153 "The USAF in Southeast Asia, 1970-1973: Lessons Learned and Recommendations," HQ PACAF, Corona Harvest, n.d., 92-96. AFHRA file no. K717.0423-11.
154 Lavalle, *The Tale of Two Bridges*, 187-188. See also Gilster, *The Air War Over Southeast Asia*, 100-101.
155 Tilford, *Setup*, 253-254.
156 2.6 percent of all bombs were dropped visually, 6.5 percent using LORAN, and 90.7, the vast majority, using radar guidance. "Linebacker II: USAF Bombing Survey," HQ Pacific Air Forces, April 1973, 22.

Despite their small numbers, laser-guided bombs scored a disproportionate amount of damage to critical targets. According to the Air Force's postwar bombing survey guided bombs were the most effective weapon against bridges and power plants, including the previously untouched thermal power plant in downtown Hanoi.[157] The survey's simple linear regression analysis calculated that visual bombing was eight times and laser-guided bombing was 124 times more effective than radar bombing in terms of target destruction. This econometric analysis, however, could account for only forty-five percent of the variation in damage to targets. In other words, the quantified relationship between target destruction and delivery method left most of the difference between the damage intended and the actual result unexplained.

The successful use of guided weapons was only part of the larger success of the operation. Besides dropping guided munitions during windows of opportunity, F-4 fighter aircraft also laid chaff clouds over high threat areas, flew escort and combat air patrols, and served as LORAN Pathfinders guiding other aircraft to targets.[158] F-111's successfully bombed the long and narrow dock area in Hanoi with unguided munitions without damaging surrounding civilian structures.[159] Although sensational reports in the international press estimated as many as 24,000 civilian casualties in Hanoi alone, overall accuracy was good and there was little collateral damage.[160] Careful planning and great care in weapons delivery (as well as the North's evacuation of major cities) left Hanoi's

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AFHRA file no. K717.64-8; and Gilster, *The Air War Over Southeast Asia*, 75-115. The bombing survey gives a simple linear econometric analysis of the effectiveness of the various release systems.
[157] "Linebacker II: USAF Bombing Survey," 21-26.
[158] Vogt interview, 73-74, 89-90, and 94-95.
[159] Futrell, *Ideas, Concepts, Doctrine*, 2, 297 and 481-482.
[160] Clodfelter, *The Limits of Air Power*, 117-118.

final tally of civilian casualties during the eleven-day campaign at 1,318 killed, 1,216 wounded, with another 305 dead in the port city of Haiphong.[161]

Heavy, all-weather B-52 bombers, released from their "tactical" roles in the South to bomb "strategic" targets in the north, played an important role in the campaign despite their inability to drop guided weapons.[162] Strategic Air Command B-52s, flown by crews trained for nuclear missions where it made little difference if you were several thousand feet off the target, had to take extraordinary measures to achieve the accuracy needed to avoid collateral damage. The B-52s had proved to be very accurate in bombing troop positions in the South using the Skyspot ground radar system, but in the North they had to rely on their own radar under much more threatening conditions.[163] To increase bombing accuracy, B-52's flew in cells of three aircraft maintaining stabilized flight (i.e., without maneuvering to avoid surface-to-air missiles) for four minutes prior to bomb release. On egress, the bombers performed a 100-degree turn that left them exposed to the surface-to-air missiles thrown up into their predictable flight paths.

The result of these unvarying bombing tactics was hardly surprising – the North shot down three B-52s on the first night and six on the third. Commanders feared further losses might compromise SAC's strategic mission against the Soviet Union.[164] Losses declined after a stand-down of the bombers on December 25th that gave time for planners at SAC headquarters in Omaha to digest the recommendations from aircrews, to revise tactics and procedures, and to improve electronic counter measures. Discriminate bombing with B-52s, however, had come at a price. In all of the B-52 missions before

[161] Clodfelter, *The Limits of Air Power*, 195. Vogt interview, 90-92.
[162] Werrell, "Linebacker II." Parks, "Linebacker and the Laws of War."
[163] Thompson, *To Hanoi and Back*, 260.
[164] Mrozek, *Air Power and the Ground War in Vietnam*, 40-41.

December, only one aircraft had been lost in combat. During LINEBACKER II, the Air Force lost a total of fifteen B-52s with another twenty-five damaged.[165]

Most of the aircraft losses in LINEBACKER II were the result of the improved network of surface-to-air missiles in the North, including a substantial numbers of SA-7 shoulder-fired, infrared missiles that lacked radar emissions and were difficult to track because of their portability.[166] New radar bandwidths and better emission control by the North Vietnamese also reduced the effectiveness of hunter (F-105)/killer (F-4) teams sent out to suppress the surface-to-air threat.[167] This threat subsided after sixteen LORAN-guided F-4's bombing through a solid overcast from 20,000 feet destroyed an important missile assembly plant with minimal civilian losses or collateral damage and no aircraft losses despite the forty-eight surface-to-air missiles fired at the formation.[168] After this attack, the North quickly exhausted its remaining supply of missiles; by 29 December, the shortage of usable missiles made further defense untenable.[169] Defenseless against continued bombing, negotiators from the North signaled their intent to return to the bargaining table.

According to one SAC study conducted immediately after the war, the actual circular error probable of B-52 strikes had been 2700 feet instead of the 800 feet predicted.[170] There were also several seemingly inevitable cases of misplaced bombs that cause collateral damage. The most deadly error occurred the night after Christmas when a B-52 dropped its bombs on homes and a market place just south of the Hanoi rail

[165] Gibson, *The Perfect War*, 415-417.
[166] On the success of North Vietnamese air defenses against B-52s as a psychological victory, see especially Marshall L. Michel III, *The 11 Days of Christmas: America's Last Vietnam Battle* (San Francisco: Encounter Books, 2002), 232-233.
[167] See especially Lavalle, *The Tale of Two Bridges*, 179-184.
[168] Parks, "Linebacker and the Law of War." Vogt interview, 92.
[169] Clodfelter, *The Limits of Air Power*, 198.

yard, reportedly killing two hundred people.[171] Imprecision, however, was perhaps not always such a bad thing. As General Vogt later related in one story that sounds almost too good to be true, one laser bomb that failed to guide crashed unintentionally into a large building in downtown Hanoi. Fearing they had inflicted unintentional civilian casualties, the aircrew reported the incident up the chain of command to PACAF Headquarters. As it turned out, rather than a local hospital or orphanage, the building happened to be the main Communist Party Headquarters for the North. As General Vogt reasoned, the anxieties the errant bomb created in the minds of the North's leadership about American targeting capabilities and intentions probably had "a salutary effect on the outcome of the negotiations."[172] Although fundamentally unpredictable, even misses have the potential for positive effects.

The Air Power Lessons of Vietnam

The perceived lessons of Vietnam are important because they have driven the transformation of the military through the present day. Each service has been shaped by its experience, and the Air Force is no exception.[173] American airmen emerged from Vietnam with the belief that air power had won the war in the eleven days of bombing in December 1972.[174] LINEBACKER II, as Don Mrozek contends, was thus the ideological equivalent to the Battle of New Orleans in the War of 1812 – a battle ambiguously related

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[170] Michel, *The 11 Days of Christmas*, 222-223.
[171] Thompson, *To Hanoi and Back*, 263.
[172] Vogt interview, 137-138. Thompson, *To Hanoi and Back*, 278-279.
[173] See Head, *War from Above the Clouds*, 87.
[174] As the Commander of Pacific Command during ROLLING THUNDER later recalled, "Whatever else may be argued, the fact is that the eleven-day air campaign of December 1972 will go down in history as a testimonial to the efficiency of air power." Sharp, *Strategy for Defeat*, 252.

to the outcome of the war, yet fundamental for reinforcing long-held myths and beliefs.[175] In the minds of airmen, the breaking of bridges in Vietnam, like the breaking of dams in the final days of the Korean conflict, was the direct cause of the subsequent armistice in January (*post hoc ergo propter hoc*). A successful outcome in Vietnam not only reinforced Air Force convictions about strategic bombing, but also led to the direct analytical linkage of the tactical success of precision air power with desired strategic and political consequences.[176]

This air power myth, however, fails to account for the underlying complexities of causation. At the level of national strategy, LINEBACKER II was contingent on the Nixon administration's political will and the ability to muster the necessary resources for the campaign, itself dependent upon dwindling fears of Chinese and Soviet intervention. During LINEBACKER II, unlike in ROLLING THUNDER, the Air Force faced an enemy more isolated from external support and therefore more susceptible to coercion through bombing, whether guided or unguided. Although counted as a victory, the size and intensity of the LINEBACKER II operation was perhaps out of proportion with the outcome attained.[177] The agreements made in January differed little from those of October, despite the tonnage dropped on the North Vietnamese. The costs of the operation and the war as a whole went beyond the losses in men and material that could be quantified by the military services. The discredited reputation of the American military, the rising cult of secrecy in the executive branch, and the decline in credibility

[175] Mrozek, *Air Power and the Ground War in Vietnam*, 165.
[176] Tilford, Jr., *Setup*, 289-290.
[177] Mrozek, *Air Power and the Ground War in Vietnam*, 184.

and standing of the United States, especially in the eyes of third world nations, were all fallouts of the war.[178]

The experience of Vietnam in general, and the outcomes of the ROLLING THUNDER campaign in particular, showed that controlling the course of war requires more than just managerial efficiency. Although the rational techniques of systems analysis were and are indispensable in selecting and managing new technologies, they fail to adequately explain, as Clausewitz noted, "the use of force under the conditions of danger, subject to constant interaction with an adversary, [and] the effects of spirit and courage to achieve a desired end" [179] "Scientific" methods of control of the air war in Vietnam led to the quantitative (and therefore assumingly more objective) measurement of sortie rates and truck counts that overshadowed less tangible measures more appropriate to the complex and uncertain nature of war, like the effects of bombing on enemy strategy and the contributions of air power to national strategic and political ends.[180]

Second generation guided air weapons, much improved over earlier guided weapons, reached operational maturity by the end of the Vietnam War. Throughout the war, American airplanes dropped some 28,000 laser-guided bombs over Southeast Asia, more than triple the number used in the first Gulf War in 1991.[181] Precision munitions allowed planners to expand target lists, since there was less fear of collateral damage.

[178] Mrozek, *Air Power and the Ground War in Vietnam*, 104-106.
[179] Clausewitz, *On War*, 133.
[180] Brodie, *War and Politics*, 474. As Mrozek later wrote, "Given the contingency of the values with which we might evaluate the war, and given the complexity of the war on its own terms, it is doubtful that any 'true and comprehensive picture' of Vietnam will ever develop – at least none with clear lines, sharp contrasts, and all the nuances of hue and shading. ...In the end, perhaps the phrase most pertinent will not be 'the horror of Vietnam' but 'the horror of uncertainty.'" Donald J. Mrozek, *The U.S. Air Force After Vietnam: Postwar Challenges and Potential for Responses* (Maxwell AFB, AL: Air University Press, 1988), 2.

Fewer airplanes were required to make sure targets were actually hit. But guided weapons were still technologically imperfect, more expensive than dumb bombs, and ultimately a limited resource – despite their impressive numbers, guided bombs represented less than 1% of all bombs dropped during the Vietnam War.

Old technologies did not immediately disappear with the emergence of new technologies. Precision bombing in Vietnam took the combined effort of many air power assets.[182] Each military situation is unique, and therefore will require new approaches. The air war in Vietnam demanded not only new technologies, but also new ways of employing old technologies, like the conversion of transports into gunships and the use of aircraft like the F-105 and the B-52 designed for nuclear war in conventional roles. There was synergistic value in having different types of weapons and delivery methods available should enemy countermeasures or the operational environment negate the effectiveness of any single method.[183] Unguided weapons, for example, were a necessity at night and in bad weather when optically and laser-guided weapons were effectively unusable. Unguided weapons were also more cost effective for hitting large area-type targets like troop concentrations, petroleum storage farms, and truck parks where no precise point of vulnerability could be identified.[184] Guided and unguided weapons were not competing, but complementary.

While innovation is important, it is also prone to overemphasis. Tactical and technological breakthroughs, in the end, are only as good as the strategies with which they are paired and how well these strategies meet the demands of the operational

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[181] Thompson, *To Hanoi and Back*, 219.
[182] Blackwelder, *The Long Road to Desert Storm*, 31.
[183] "The USAF in Southeast Asia, 1970-1973: Lessons Learned and Recommendations," HQ PACAF, Corona Harvest, n.d., 84-85. AFHRA file no. K717.0423-11.

environment.[185] Although precision weapons proved tactically effective in Vietnam, their lethality diverted attention from air power's strategic and political limits.[186] Technology and firepower alone, no matter how discriminate and precise, were a poor substitute for effective strategy. The possibilities of tactical and technological precision came to the fore during Vietnam. These air power possibilities were tempered, however, by technical constraints, the lack of a tested operational doctrine, the geography and climate of Southeast Asia, and the changing political landscape and played only a limited role in shaping the war's ultimate outcome.

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[184] See especially "Guided Bombs- Problems of Utility and Cost," Operations Analysis Headquarters, USAF, February 1971. AFHRA file no. K143.504-32.

[185] As Mrozek cautions, "Certainly, innovation is not inherently a poor or risky business, but it is not inherently beneficial either. Its success depends upon pertinence to the situation, and pertinence is often decided in a turmoil of competing ideas driven by predispositions and clouded by illusions of scientific neutrality." Donald J. Mrozek, "The Limits of Innovation: Aspects of Air Power in Vietnam." *Air University Review* 36/2 (January-February 1985).

[186] Clodfelter, *The Limits of Air Power*, 203. Bernard Brodie, reflecting on the failing war in Vietnam in the spring of 1972, advised "stress[ing] the importance of the political side of strategy to the simply technical and technological side. Preserve and cherish the systems analysts, but avoid the genuflections." Bernard Brodie, "Why Were We So (Strategically) Wrong?" *Foreign Policy* 5 (Spring 1972), 161.

From Tactical Precision to Strategic Effects

"The more mechanical become the weapons with which we fight, the less mechanical must be the spirit which controls them."

J.F.C. Fuller[1]

The success of the LINEBACKER campaigns in 1972, set against the failure of ROLLING THUNDER, highlighted the emerging capabilities of precision-guided air weapons. Technological developments after Vietnam built upon the foundations of this revolution, producing truly effective guided weapons for both air and land warfare. The technological "transformation" of air power, however, involved more than just increasingly accurate weapons. Other technological advances that interacted with and enabled the new capabilities included stealthy penetration, improved reconnaissance and tracking of potential targets, and an infrastructure capable of handling a greater flow of information.[2] Precision weapons by themselves were not silver bullets; fully exploiting their advantages required many supporting technological systems.

The technological revolution was not without its skeptics. In the late 1970's, a group collectively known as the "Defense Reformers" argued that money was better spent on low-technology solutions to military problems. The Defense Reformers' contention went beyond the issue of quantity versus quality, involving a notion of the inherent unpredictability of war in general and the human element in particular, and the need for more flexible and adaptive weapon systems. This moderating notion, even

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[1] J.F.C. Fuller, *Generalship, Its Diseases and Their Cure: A Study of The Personal Factor in Command* (Harrisburg, PA: Military Service Publishing Co., 1936), 13.
[2] See especially William Perry, "Desert Storm and Deterrence," *Foreign Affairs* 70/4 (Fall 1991).

more than the weapon systems they promoted, was the reformers' most valuable contribution to the post-Vietnam transformation of the American military.

The Persian Gulf War in 1991 confirmed the truly revolutionary value of the new air power technologies.[3] But the application of precision air power during DESERT STORM also supported the reformers' assertions about the nature of war and the consequences of nonlinearity for air warfare. The war was a unique case where, despite the overwhelming weight of coalition air power and Iraqi military incompetence, outcomes were not entirely predetermined. Although technological systems were more dependable, results were still contingent on effectively random events that occurred throughout the war. Unintended tactical incidents, like civilian casualties in the bombing of the Al Firdos bunker, inflated to strategic importance by the ever-present media, produced unanticipated consequences for the air campaign. Air power successfully attacked many targets, but the ultimate effects of attacking these targets and the ways in which aerial attack related to the ultimate outcome was unclear.[4] While undeniably "a new and exciting chapter on air power" (as General Buster Glosson later asserted), the 1991 Gulf War against Iraq is a chapter that nevertheless deserves more careful reading.[5]

Air theorists like John Warden and David Deptula, seeking to explain the successes of the air war, advocated three interrelated concepts. The first was a more holistic appreciation for the enemy as a system and the vulnerabilities of this system to air power. The second was the idea of parallel or hyper war – war waged at such a rate

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[3] See especially Benjamin S. Lambeth, *The Transformation of American Air Power* (Ithaca, NY: Cornell University Press, 2000), 1.

[4] For a taste of this debate, see Stephen J. Biddle, "Victory Misunderstood: What the Gulf War Tells Us About Future Combat," *International Security* 21/2 (Autumn 1996), 139-179; and the reply from Thomas Keaney, Thomas Mahnken, and Barry Watts in *International Security* 22/2 (Autumn 1997), 147-162. See also Robert A. Pape, "The Limits of Precision-Guided Air Power," *Security Studies* 7/2 (Winter 1997/1998), 93-114 and responses from Barry Watts and John Warden that follow in the same issue.

and intensity that it paralyzes an enemy, effectively precluding reaction and adaptation. Finally, the concept of effects-based operations argued for greater consideration of the higher order, functional effects of bombing versus traditional considerations of physical destruction. None of these air power ideas was entirely new. Yet, when combined with the increasing use of the lens of nonlinearity in the study of air warfare, these ideas brought the potential for a theoretical transformation to accompany air power's technological transformation, for a conceptual shift away from the mechanical certainty of precision technology into the less tangible realm of its strategic and political effects.

The Precision Revolution

Some of the first attempts at deciphering the impacts of precision weapons on warfare in general and air warfare in particular after the LINEBACKER campaigns came from the think tank at the RAND Corporation, most notably from analyst James Digby.[6] Digby, who emphasized the qualitative differences of the new weapons, was concerned not only with what the new weapons could do *for* the U. S. military, but also what they could do *to* it, both in the air and on the ground.[7] Digby drew his conclusions from the 1972 campaigns in Vietnam and the October 1973 war in the Middle East, which analysts saw as more representative of a future conventional conflict between NATO and the

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[5] Glosson, "Impact of Precision Weapons," 4.

[6] Another analyst originally associated with RAND who heralded the revolution in weapons' accuracy was Albert Wohlstetter. Wohlstetter saw innovations in weapons' guidance as "in some ways more revolutionary than the transition from conventional to fission explosives or even fusion weapons." Albert Wohlstetter, "Bishops, Statesmen, and Other Strategists on the Bombing of Innocents," *Commentary* (June 1983), 21-22. See also Andrew J. Bacevich, *The New American Militarism: How Americans are Seduced by War* (New York: Oxford University Press, 2005), 154-165.

[7] See especially James Digby, *Precision-Guided Munitions*, Adelphi Paper No. 118 (London: The International Institute for Strategic Studies, 1975).

Warsaw Pact.[8] Both of these conflicts demonstrated the potential efficiency of precision-guided munitions in killing individual tanks, planes and ships. Precision-guided ground weapons like the Soviet SA-7 anti-aircraft missile and AT-3 anti-tank missile, in particular, had been especially deadly. Digby's first proposition was, therefore, that precision munitions favored the defender, at least until the range of offensive weapons increased or there were better systems for target acquisition and tracking.[9] Concealed defenders held an advantage in acquiring targets, whereas forces concentrating for the offensive were more vulnerable to precision strikes. This was especially true for air defenses where the high contrast of aircraft against the relatively blank sky made target acquisition easier.[10] Aircraft survivability was therefore a critical issue and the resulting conclusion (a conclusion that later proved false) was that precision-guided surface to air missiles had rendered tactical aircraft obsolete.[11]

Digby's second proposition was that precision weapons, even though they caused the dispersal of units on the battlefield, increased both the pace and intensity of war by giving greater destructive power to even the smallest unit. Although they were more expensive than "dumb" weapon systems they replaced, precisely guided weapons were relatively cheap compared to the tanks, ships, and aircraft they could destroy. The cost

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[8] During the 1973 Yom Kippur war in the Middle East, the Israelis successfully used optically guided Walleyes and HOBOs against Arab armored forces, as well as bridges, fortifications, and buildings. Donald I. Blackwelder, *The Long Road to DESERT STORM and Beyond: The Development of Precision Guided Bombs* (Maxwell AFB, AL: School of Advanced Airpower Studies, May 1992), 32.

[9] Albert Wohlstetter similarly wrote that "technologies of discrimination and control" were particularly important in the defense. See, for example, Albert Wohlstetter, "Threats and Promises of Peace," *Orbis* (Fall 1973), 1122-1124.

[10] The shoulder-launched SA-7 used infrared homing to deliver a 1.1 kg warhead. The Soviet AT-3 Sagger, like the American TOW missile first used in Vietnam, was a wire-guided anti-tank round that required the shooter to "fly" the weapon to the target. On the benefits of guided weaponry to the defense, see S. J. Dudzinsky and James Digby, *The Strategic and Tactical Implications of New Weapons Technologies*, RAND Report P-5765 (December 1976), 25; and Digby, *Precision-Guided Munitions*, 5.

[11] Robert F. Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1961-1984*, Volume 2 (Maxwell AFB, AL: Air University Press, 1989), 483-485.

effectiveness of precision weapons, Digby proposed, would therefore usher in "a new war of numbers." Finally, Digby correctly predicted that precision weapons would further change the character of war by reversing the trend toward targeting non-military systems and civilian populations, since military targets could now be destroyed with less total explosive power and less collateral damage.[12]

Precision was not only changing the mechanics of the battlefield, but also how military theory and theorists thought about warfare. RAND analysts holding a seminar in the fall of 1972 on the impacts of precision weapons in air and land warfare noted a shift in military thinking from measures of tactical efficiency to military effectiveness. "There are clearly changes coming with respect to judgments involving military relevance, military worth, and military success. The trend of these developments is away from the values of scale as measures of military effectiveness – that is, counting the number of sorties, the number of bombs dropped, and so on." The seminar also noted the blurring of the distinction between tactical nuclear weapons and improved conventional munitions.[13] Because accuracy was no longer strictly a function of range as it had been throughout the history of missile weapons, precision guidance was narrowing the gap between the tactical and strategic. Precision weapons were indifferent to the type of delivery vehicle that brought them to the launch point; the effects of precision munitions on their intended targets were more important than the mechanics of their delivery.

[12] Digby, *Precision-Guided Munitions*, 12-13.
[13] Gordon A. R. Graham, *Seminar on the Implications of Precision-Guided Munitions: Vol. 1 A Summary Report*, RAND Report No. R-1247-ARPA (April 1973), 2 and 15. To further narrow this gap, another study at Air University advocated equipping strategic bombers with large precision guided conventional bombs (10-20,000 pounds), creating "a new middle-ground between the use of conventional and nuclear systems," for more effective strikes against hardened targets when collateral damage remained a concern. George A. Irvin, *Precision Guided Munitions with Large Conventional Bombs* (Maxwell AFB, AL: Air War College, Air University, April 1975), 8.

Consequently, as James Digby observed, "...the familiar labels 'strategic missions' and 'tactical missions' may now impede thought more than they can help it."[14]

Although official Air Force efforts to evaluate the experience of air power in Vietnam like CHECO (Contemporary Historical Evaluation of Current Operations) and CORONA HARVEST collected vast amounts of data, analysts tailored much of this data to computerized reporting systems – sortie rates, bomb tonnages, and the rates at which air power could perform its assigned tasks. Data essentially ended when bombs were dropped, neglecting broader measures of the *effectiveness* of bombing, including higher order effects on enemy systems. Individual interests and parochial views of the Air Force commands also skewed the surveys, causing inconsistencies in the various final reports. The two principal directors of CORONA HARVEST, like analysts from RAND, drew attention to the misplaced focus on efficiency rather than effectiveness, which could only be measured in terms of air power's impact "on the enemy or enemy's will to operate." Their suggestions for improving future surveys included revising Air Force reporting procedures "to gather material and data customized to support Air Force effectiveness studies."[15]

General Momyer, recalled from retirement to appraise the recommendations of the CORONA HARVEST reports, similarly highlighted the need for less tangible measures of air power effectiveness. "The measure of effectiveness must be sought in subjective assessments of the effects air attack had on the ability of the enemy to sustain combat and what would have been the results if our own ground forces did not have air

[14] James Digby, *The Technology of Precision Guidance – Changing Weapons Priorities, New Roles, New Opportunities*, RAND Report P-5537 (November 1975), 7-8.

support.... I think we can measure how well our weapons perform, how well our pilots do and how good our doctrine is, but how effective we are remains a subjective matter."[16] The first steps in the shift from quantified calculations of friendly effort toward a greater appreciation for air power's effects on the enemy came from attempts to proffer lessons from the difficult experience of Vietnam.

The airman's response to Vietnam was much like the response to Korea – never again. Putting the uncertain experience with limited war aside, the Air Force turned their attention to air power in the context of a general, high-intensity war with the Soviets.[17] In the wake of Vietnam, the military faced numerous pressures for greater efficiency – in military budgets, in numbers of military personnel in uniform, in forces deployed overseas, and in reducing the collateral damage of military operations. Within this context, precision firepower offered the "leaner, more mobile, more streamlined" Air Force envisioned by Secretary of the Air Force Robert Seamans an efficient and effective solution to the challenge of fighting a conventional war against the Soviets outnumbered.[18]

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[15] Robert F. Futrell, *Ideas, Concepts, Doctrine*, 2, 316-323; William P. Head, *War from above the Clouds: B-52 Operations during the Second Indochina War and the Effects of the Air War on Theory and Doctrine* (Maxwell AFB, AL: Air University Press, 2002), 35-40.

[16] Memorandum by Gen. W.W. Momyer to General Ellis on CORONA HARVEST, 1 July 1974. Quoted in Futrell, *Ideas, Concepts, Doctrine*, 2, 323.

[17] "Thus," writes Donald Mrozek, "interpreting Vietnam in falsely neat terms supported the focusing of maximum attention on wars of least likelihood while suggesting minimum accommodation for wars of greatest probability." Donald J. Mrozek, *The U.S. Air Force After Vietnam: Postwar Challenges and Potential for Responses* (Maxwell AFB, AL: Air University Press, 1988), 15.

[18] Secretary of the Air Force Robert C. Seamans, Jr. to the House Committee on Defense Appropriations, 1971. Quoted in Futrell, *Ideas, Concepts, Doctrine*, 2, 556. As one prominent Air Force historian has written, "The struggle for Southeast Asia helped to transform the Air Force from an almost total focus on potential nuclear warfare against the Soviet Union into a more varied and flexible force wielding increasingly sophisticated conventional weapons." Wayne Thompson, *To Hanoi and Back: The United States Air Force and North Vietnam, 1966-1973* (Washington, D.C.: Air Force History and Museums Program, 2000), v.

The United States and their NATO allies turned from a strategy of conventional forces as a nuclear trip wire against Soviet aggression to a scheme for tactical defense with conventional precision weapons. The capabilities of precision weapons inspired a near obsession with the benefits of tactical firepower, not just in the Air Force, but in the Army as well. As the military chiefs reported to the Senate in 1971, "The Russians are overweight in tanks. If you can stop their tanks, you can blunt their attack. Therefore, every means at our disposal must be used to kill his armored vehicles."[19] The U.S. Army's doctrinal manual FM 100-5 *Operations* published in 1976 centered on firepower and the strength of the defense, advocating the use of the "new lethality" of technology to "fight outnumbered and win."[20]

The Air Force therefore pursued the continued development of precision-guided air weapons with a great sense of urgency, unlike after the Korean War. The most important technological improvements in precision weapons between Vietnam and the Gulf War involved more capable sensors, particularly for night and low visibility conditions. Chief among these was infrared – high-resolution thermal imaging – for target detection and tracking. Infrared was so successful as a means for guidance at night and in the weather that in 1978 the Air Force cancelled further development of the laser-guided Maverick anti-tank missile in favor of an infrared version; the infrared seeker developed for the Maverick was later attached to the GBU-15 television-guided bomb to improve its capabilities.[21]

[19] Quoted in Futrell, *Ideas, Concepts, Doctrine*, 2, 491.
[20] John L. Romjue, "AirLand Battle: The Historical Background," *Military Review* (March 1986), 53. See also Futrell, *Ideas, Concepts, Doctrine*, 2, 549.
[21] Futrell, *Ideas, Concepts, Doctrine*, 2, 559-560.

The PAVE TACK was another infrared targeting pod developed from the PAVE SPIKE pod used on the F-4E during Vietnam. Employed on the F-4 and F-111, the PAVE TACK combined high-resolution infrared imaging with a highly accurate laser designator and an inertial navigation system that further mitigated the effects of darkness, intervening dust or smoke, and enemy concealment. Besides being particularly effective for delivering laser-guided munitions at night, the PAVE TACK system could also assist with delivery computations for unguided munitions.[22]

Another important technological advance in precision targeting was the LANTIRN (low-altitude navigating and targeting infrared for night) system, whose development began in 1979.[23] The LANTIRN system consisted of two externally mounted pods, a navigation pod with terrain following radar and a targeting pod with a more narrowly focused infrared beam and self-contained laser designator. Combined with a heads-up display that superimposed information on the windscreen in front of the pilot, LANTIRN gave the F-15E and later the F-16C an integrated capability to navigate, and then target, designate, and destroy targets at night.

Because of its technological complexity, operational testing and evaluation of the LANTIRN system was not yet completed at the time of the Iraqi invasion of Kuwait in 1990. Only two squadrons of F-16s that deployed for the subsequent war had the LANTIRN navigational pods. Although all of the F-15Es deployed were equipped with navigational pods, only a handful had targeting pods. Furthermore, sandblasting of the seeker windows in desert conditions caused imagery degradation.[24] Though the system

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[22] *Gulf War Air Power Survey, Vol. IV: Weapons, Tactics, and Training* (Washington, D.C.: Government Printing Office, 1993), 229.
[23] Futrell, *Ideas, Concepts, Doctrine*, 2, 562-564.
[24] *GWAPS, Vol. IV: Weapons, Tactics, and Training*, 46, 88, and 228.

held great potential, it was not until after DESERT STORM with quantity production and the development of a harder coating for sensor windows that LANTIRN came to the fore as one of the most important guidance systems in the Air Force arsenal.[25]

Other developments in target sensing included the AGM-88 HARM (high-speed anti-radiation missile), an upgrade of the AGM-45 SHRIKE used against Vietnamese air defenses, that could detect a wider array of radar emitters. The combined significance of the new sensors was not only that they exposed more enemy assets to potential destruction, but also that they opened an expanded window for air-to-ground attack with precision weapons. By the time of DESERT STORM, airmen, thanks to the new capabilities, could now fight a "twenty-four-hour air war" and the tempo of operations varied little between day and night.[26]

The Air Force also continued the pursuit of greater standoff capability, following the tradition of Hap Arnold's Bug, the Weary Willies, and glide bombs. More successful than earlier attempts, the AGM-86C conventional air-launched cruise missile (CALCM) was added to the operational inventory in 1988.[27] General David C. Jones, Chief of Staff of the Air Force, and Thomas C. Reed, Secretary of the Air Force, described the air-launched cruise missile to Congress as "a new technology meriting the word 'breakthrough'" that offered "a tenfold improvement in accuracy over earlier cruise missiles such as the Hound Dog at a projected decrease in cost in constant dollars."[28] The conventional version, a 1000-pound bomb attached to a delivery vehicle originally

[25] *GWAPS, Vol. III: Logistics and Support*, 324.
[26] *GWAPS, Vol. IV: Weapons, Tactics, and Training*, 266-273.
[27] Futrell, *Ideas, Concepts, Doctrine*, 2, 410-417; Kenneth P. Werrell, *Chasing the Silver Bullet: U.S. Air Force Weapons Development from Vietnam to DESERT STORM* (Washington, D.C.: Smithsonian Books, 2003), 233-236.

intended for nuclear warheads, was carried into the air by a B-52 and then launched outside the range of enemy defenses. The CALCM would then fly autonomously using an inertial navigation system to within 100 feet of a target, day or night. The version of the CALCM employed in the Gulf War added navigational guidance from Global Positioning Satellites (GPS), although satellite coverage was still limited to certain hours and certain geographical areas.[29] Thirty-five of the thirty-nine CALCMs employed during DESERT STORM were launched successfully in the first twenty-four hours of the air war against heavily defended targets considered inaccessible to manned aircraft.[30] While the CALCM kept aircrews out of harm's way with its long-range precision strike capability, it was expensive, required extensive pre-mission planning and programming, and therefore lacked the flexibility of other smart weapons delivered directly by aircraft.

Another measure to provide greater standoff capability was the development of "launch and leave" weaponry. With early precision weapons, a "designator" had to maintain line of sight with the target throughout bomb fall, often from within range of enemy defenses. The new 2000-pound GBU-15, on the other hand, with an electro-optical television and IR seeker, could be dropped using either the "indirect mode" where the operator would remotely fly the bomb to the target using data link technology or the "direct mode" where the weapon locked on to its target before release. The GBU-15 could also be dropped blind from above the weather and then flown to a point where the

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[28] General David C. Jones, USAF Chief of Staff, and Thomas C. Reed, Secretary of the Air Force, to John C. Stennis, Chairman, Committee on Armed Services, U.S. Senate, 22 March 1976. Quoted in Futrell, *Ideas, Concepts, Doctrine*, 2, 415.

[29] See Michael Russell Rip and James M. Hasik, *The Precision Revolution: GPS and the Future of Aerial Warfare* (Annapolis, MD: Naval Institute Press, 2002), 155-161.

[30] Launched against eight targets, the CALCMs destroyed six, damaged one, and missed another. Werrell, *Chasing the Silver Bullet*, 235. See also *GWAPS, Vol. IV: Weapons, Tactics, and Training*, 248-252.

operator could acquire the target and lock on the weapon.[31] The unclassified range of the GBU-15, equipped with controllable fins to glide to the target, is 5-10 miles.[32] In the AGM-130, the Air Force added a rocket assist unit (a concept borrowed from the Navy's anti-ship missiles) to the GBU-15, for even greater range and greater aircrew survivability.[33] The AGM-130, however, much like the LANTIRN system, only reached operational maturity after the 1991 Gulf War.[34]

The most important contribution to reducing the cost and therefore increasing the availability of precision weapons was the development of laser-guidance kits that could be fitted to various size bombs. Upgraded PAVEWAY II laser-guidance kits made their first operational appearance in 1976. They included folding tailfins that opened on release to make room within an aircraft for more bombs, improved guidance and maneuverability, improved seeker sensitivity for better detection range, and the use of mass-produced parts to provide greater commonality of components and cut production costs. Although the accuracy of the PAVEWAY II system was little improved over the PAVEWAY I bombs used in Vietnam, the new generation of laser-guided bombs were more technologically reliable.[35]

The PAVEWAY III series entered development in 1980 and came on line in the Air Force in 1986. PAVEWAY III used proportional guidance and had a much larger field of view for the laser seeker. Proportional guidance, unlike the system of full control deflections in Vietnam-era weapons (descriptively known as the "bang-bang" system),

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[31] Richard P. Hallion, *Storm Over Iraq: Air Power and the Gulf War* (Washington, D.C.: Smithsonian Books, 1992), 306. *GWAPS, Vol. IV: Weapons, Tactics, and Training*, 83-84.
[32] Paul G. Gillespie, *Precision Guided Munitions: Constructing a Bomb More Potent Than the A-Bomb*, unpublished dissertation (Lehigh University, June 2002), 198-199.
[33] Gillespie, *Precision Guided Munitions*, 200.
[34] Hallion, *Storm Over Iraq*, 307.
[35] Gillespie, *Precision Guided Munitions*, 191-193.

moved control surfaces in incremental amounts as necessary to steer the munition to target, thereby providing a smoother flight path that preserved kinetic energy and increase the glide range of the bomb. The GBU-24/27 Low-Level Laser Guided Bomb (later named the BLU-109) used an improved PAVEWAY III guidance system that included a sophisticated autopilot so that the weapon could cruise autonomously toward the target while seeking the laser designator.[36] Introduced in the late 1980's, these weapons played a prominent role in the Gulf War in 1991 – F-111s dropped 1,181 GBU-24s and F-117s dropped 739 GBU-27s.[37]

These new systems, although they were more capable than early precision-guided weapons, were not less expensive and were limited in availability. The PAVEWAY III was three to four times more expensive than the PAVEWAY II and ten times more expensive the first laser guided munitions.[38] Only a handful of aircraft types could deliver guided weapons at the time of the Gulf War. Initial stocks of munitions prepositioned on floating supply ships in the Persian Gulf consisted primarily of unguided "iron" bombs (Mk-82s and 84s). Only the five-month lead-in to the war and extraordinary efforts in production and distribution allowed the U.S. military to meet the high demands for guided bombs.[39] True cost effectiveness and battlefield ubiquity for precision air weapons came only with the Joint Direct Attack Munition (JDAM) developed and deployed after the Gulf War.

The positive results of this complex of new air weapons technologies included greater bombing accuracy, smaller bomb loads, greater lethality, greater aircraft

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[36] Charles T. Fox, *Precision Guided Munitions: Past, Present, and Future* (Maxwell AFB, AL: Air War College, Air University, April 1995), 6.
[37] *GWAPS, Vol. IV: Weapons, Tactics, and Training*, 76-77.
[38] Blackwelder, *The Long Road to DESERT STORM and Beyond*, 34-37.

maneuverability and survivability, and overall increased sortie effectiveness.[40] The technology of more accurate weapons delivery, however, was but one part of a much wider complex of systems behind the transformation of air power. As an Army War College report after Vietnam pointed out, "PGM [precision-guided munitions] technology has the potential to permit the attack of any target with great accuracy *providing* that the target is detected and located, the command and control equipment and procedures work as they should, the delivery system functions properly, and there is no interference with delivery."[41] Improved air power effectiveness, then, was not just the result of better weaponry, but was also contingent on stealthy penetration, surveillance and reconnaissance capabilities, and more robust information processing systems.

Stealth technology, when combined with the standoff capacity of the new bombs and cruise missiles, gave air power an exceptionally lethal capability. The real advantage of the F-117 (also known as "the Black Jet") was not the ordnance it could carry (only two 2000-pound bombs), but its ability to arrive over target unannounced.[42] Using a combination of radar absorbing materials and aircraft contours, stealth technology reduced the radar signature of the F-117 by ten to one hundred times of that of any other combat aircraft, making it nearly invisible to enemy radar. But as with other weapons, there were costs associated with the F-117's technological complexity. Technical problems pushed the development program over both cost and schedule. The production version was an extremely maintenance intensive aircraft. Although the Air Force purchased fifty-nine aircraft, a fifth of the fifty-nine were unable to fly at any one time

[39] *GWAPS, Vol 3: Logistics and Support*, 221-238 and 254-255.
[40] Lambeth, *The Transformation of American Air Power*, 76-77.
[41] Emphasis added. Harold G. deMoya, *The Impact of Precision Guided Munitions on Army Planning and Doctrine* (Carlisle Barracks, PA: Strategic Studies Institute, Army War College, February 1974), 2.

because of a lack of spare parts. At one time, there were seven different versions in service due to the need for modifications and the problems of standardization.[43]

The F-117's unveiling in 1989 in Panama demonstrated the new aircraft's capability, but also showed that air power success depended on more than accuracy alone. Stealth fighters dropped their bombs precisely on their intended aim points just outside Panamanian Army barracks, but were nevertheless quickly criticized in the American press for failing to neutralize Panamanian opposition, a failure in targeting strategy, not in aircraft or weapons performance.[44] The aircraft played a much larger role in the 1991 war against Iraq. "More than any single platform," noted the Gulf War Air Power Survey, "the Black Jet made Desert Storm fundamentally different tactically from previous air campaigns."[45] Throughout DESERT STORM, F-117s flew only two percent of the combat sorties yet attacked more than forty percent of the strategic targets.[46] Thanks to their stealthy penetration capabilities, F-117s flew 1,299 combat sorties, scoring 1,664 direct hits with laser-guided bombs, without sustaining any battle damage.[47]

Two aircraft systems – the Boeing E-3 Sentry Airborne Warning and Control System (AWACS) and the Grumman E-8 Joint Surveillance, Targeting, and Reconnaissance System (JSTARS) – epitomized the revolution in information systems

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[42] Lambeth, *The Transformation of American Air Power*, 74-75. On the role of the F-117 in DESERT STORM, see *GWAPS, Vol. IV, Weapons, Training, and Tactics*, 39-41.
[43] Werrell, *Chasing the Silver Bullet*, 130-136; and Stephen Budiansky, *Air Power: The Men, Machines, and Ideas That Revolutionized War, From Kitty Hawk to Gulf War II* (New York: Viking Penguin, 2004), 411-412.
[44] Merrill A. McPeak, *Selected Works, 1990-1994* (Maxwell AFB, AL: Air University Press, 1995), 2-3.
[45] *GWAPS, Vol. IV: Weapons, Tactics, and Training*, 247.
[46] James P. Coyne, *Airpower in the Gulf* (Arlington, VA: Aerospace Education Foundation, 1992), 69.
[47] *GWAPS, Vol. IV: Weapons, Tactics, and Training*, 40.

behind the transformation in air power capabilities after the Vietnam War.[48] The E-3 AWACS that first flew in 1975 was the culmination of a long series of technological developments reaching back to the 1950's that brought together the advantages of a mobile radar and airborne controllers to provide detection, early warning, and command and control to attacking aircraft. JSTARS, a joint Air Force-Army program, gave the complementary capability of detecting moving ground targets at ranges between 200 and 250 miles. This information could then be quickly transmitted to strike aircraft through the Joint Tactical Information Distribution datalink. Although a full prototype (known as PAVE MOVER) was available as early as 1985, the first two JSTARS aircraft were hurriedly deployed for the Gulf War. The results justified the effort as Iraqi forces on the move within range of JSTARS, as in the Battle of Khafji, were more vulnerable to both air and land power.[49] The information provided by AWACS about enemy air threats and by JSTARS about mobile ground targets was a necessary component that enabled American precision air power.

Although the new capabilities of air power brought significant advantages, they also presented potential complications. The ability to strike targets precisely increased the demand for information. As precision-guided munitions approached near-zero circular error probables, planners and operators needed to know not just which objects on the ground to hit, but more precisely where to put the "desired mean point of impact" (DMPI) on each object for the greatest effect and the least amount of collateral damage.[50] Precision also demanded more accurate battle damage assessment to measure the effects

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[48] See especially Werrell, *Chasing the Silver Bullet*, 187-205.
[49] Hallion, *Storm Over Iraq*, 310-311. *GWAPS, Vol. II, Part 2: Effects and Effectiveness*, 233 and 238-240.
[50] For a discussion on circular error probable and DMPIs, see *GWAPS, Vol. IV: Weapons, Tactics, and Training*, 86-87.

of bombing and assess collateral damage. Standoff capabilities that allow strikes beyond visual range complicated feedback and retargeting since there was often no post-strike picture for battle damage assessment, especially with autonomous weapons lacking cameras in the nose of the bomb.[51] Precision capabilities further taxed scarce surveillance resources like unmanned aerial vehicles and satellites and burdened the pipelines carrying the necessary information.[52]

Faced with a growing array of information gathering systems (space-based assets, tactical reconnaissance, and battlefield sensors) and an expanding choice of precision air weapons, the targeting equation – matching the right weapons to the right targets – has become much more complex, requiring larger air planning and operations centers manned by more and more people.[53] The size of the Combined Air Operations Center, for example, doubled to 500 people between the Gulf War in 1991 and Operation DELIBERATE FORCE in 1995, and then doubled again for Operation ALLIED FORCE in 1999.[54] Interdependent information and control systems demonstrably increase the returns on precision air power, but at the same time they create other potential risks: centralized command and control nodes vulnerable to weapons of mass destruction; human, bureaucratic, and managerial dysfunction from the overabundance of data; and a

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[51] Edward Luttwak, "Air Power in US Military Strategy," in Richard H. Shultz, Jr. and Robert L. Pfaltzgraff, Jr., eds, *The Future of Air Power in the Aftermath of the Gulf War* (Maxwell AFB, AL: Air University Press, 1992), 29.
[52] On the additional information required for effects-based targeting in DESERT STORM, see David A. Deptula, *Effects-Based Operations: Change in the Nature of Warfare* (Arlington, VA: Aerospace Education Foundation, 2001), 12.
[53] Fox, *Precision Guided Munitions*, 14-15.
[54] Stuart Peach, "Air Warfare: A Contemporary Perspective," in Christopher Finn, ed., *Effects Based Warfare* (London: The Stationery Office, 2003), 89-92.

dependence on information that makes organizations more susceptible to deliberate disinformation.[55]

Precision weapons, while they have decreased the probability of unintended collateral damage, have increased the impacts of this damage when it occurs. Precision-guided weapons, because of their capabilities for discrimination, have expanded target lists to include sites in urban and other areas previously considered too hazardous to attack. The expansion of target lists increases the demands of mission planning while creating a window for enemy exploitation by placing high value military targets next to sensitive civilian sites.[56] Expectations of precision make reports of mistakes all the more politically significant. Instantaneous global news coverage provides feedback loops that magnify minor errors, turning tactical misses of only a few feet into the political equivalent of a miss of many miles.

The 1986 raid on Libya, where PAVE TACK-equipped F-111's dropped laser-guided bombs against targets tucked in the close quarters of Tripoli, offers a case in point.[57] The desire to limit collateral damage compelled the use of laser-guided bombs delivered by F-111's against targets in downtown Tripoli (despite uncertainties about the delivery of precision weapons at night while flying 200 feet above the ground at 500 miles per hour).[58] Up against sophisticated Libyan air defenses, the F-111s used the "Pave Tack Toss," where a low flying aircraft would pop up to loft a laser-guided bomb

[55] See especially Thomas Keaney and Eliot Cohen, *Revolution in Warfare? Air Power in the Persian Gulf* (Annapolis, MD: Naval Institute Press, 1995), 216-219.
[56] Mets, *The Long Search for a Surgical Strike*, 39.
[57] On the complexities of the El Dorado Canyon, see Robert E. Venkus, *Raid on Qaddafi: The Untold Story of History's Longest Fighter Mission by the Pilot Who Directed It* (New York: St. Martin's Press, 1992). See also David C. Martin, *Best Laid Plans: The Inside Story of America's War Against Terrorism* (New York: Harper & Row, 1988), 258-322.

toward the target and then turn away toward safety while the weapons system officer "lased" the target. In the heat of combat, several of the pilots flew aggressive egress paths that caused the airplane's tail to obscure the laser designator, leaving bombs to fall unguided. Planning mistakes also contributed to less-than-precise bombing as planners allowed for only thirty-second spacing between laser-guided bombs, even though it took a full minute for the debris of a GBU-10 2000-pound bomb to clear. The string of F-111's also dropped on the closest aim point first, making it increasingly difficult for succeeding aircraft to identify and hit their targets through the debris and smoke from earlier bombs.[59]

Despite desires to avoid civilian casualties, the joint raid by the Air Force and Navy killed a total of thirty-seven Libyans and wounded another ninety.[60] In one incident, a weapons systems officer had trouble finding his intended target after bomb release and the bomb veered ballistically onto an apartment complex near the French Embassy in downtown Tripoli. Of the eighteen laser-guided bombs dropped by F-111's over Tripoli, only four are thought to have hit their target. As the chief planner of the mission concluded, "El Dorado Canyon would prove once again that precision bombing is often imprecise – the realities of combat make it possible to limit, but never totally eliminate, unintended casualties."[61]

Besides demonstrating the difficulties of using air power as a surgical instrument, the operation showed the impact of information feedback loops in exaggerating bombing errors and magnifying their political effects. One senior member of Congress emerged

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[58] Lambeth, *The Transformation of American Air Power*, 100-102. The Air Force decided against using the still-secret F-117 stealth fighter to prevent prematurely revealing its capabilities to the Soviets. Martin, *Best Laid Plans*, 315.
[59] Venkus, *Raid on Qaddafi*, 10, 50-51.

from a classified briefing to tell reporters to turn on their television sets at around 6:00 that evening.[62] With bombs falling on Tripoli just as the Monday evening newscasts began on the East Coast, viewers heard F-111's rumbling over downtown Tripoli via a phone call from an on-scene reporter. The international media, especially in Europe where fears of retaliation were greatest, immediately broadcast news of the errant bomb that hit the French Embassy and the reports of civilian casualties.[63] A briefing by the Secretary of State and Secretary of Defense less than three hours after the attack (even before air crews had returned to England) that gave short shrift to reporters' concerns about collateral damage only increased speculations about the imprecision of the raid.[64] The end result was the amplification of the negative political effects of the misses, including sharp European criticism of what seemed an increasingly militarized American foreign policy.[65]

The Counter-Revolution

As the Soviets improved their night and all-weather capabilities in the late 1970's, the American qualitative advantage in weapons systems appeared to be fading.[66] High tech weaponry, therefore, represented less of an American advantage. The "Defense Reformers," a disparate group of Pentagon insiders, journalists, and academics that included Chuck Spinney, Pierre Sprey, Bill Lind, and in Congress, Senator Gary Hart and

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[60] Venkus, *Raid on Qaddafi*, 145-146.
[61] Venkus, *Raid on Qaddafi*, 112.
[62] Weinberger, *Fighting for Peace*, 193.
[63] Venkus, *Raid on Qaddafi*, 122. Weinberger, *Fighting for Peace*, 197.
[64] Venkus, *Raid on Qaddafi*, 115-116.
[65] As Secretary of Defense Weinberger later wrote about the difficulties of the operation and its unintended consequences, "All actions of that kind are not only immensely complex, but are subject to all manner of events that cannot be predicted, not matter how carefully, or for how long, the action is planned." Weinberger, *Fighting for Peace*, 197.

the members of the Congressional Military Reform Caucus founded in 1981, argued that the increasing complexity of American weapons' systems could potentially reduce overall combat effectiveness.[67] The Rosetta stone of the Defense Reformers was Air Force Colonel John Boyd's "Patterns of Conflict" briefing that sought military solutions in hard-thought strategy, not high technology.[68] The Reformers were not outright Luddites looking to abandon technology. Instead, they argued that in the context of future conflict with the Soviet Union the U.S. military should focus on "simply brilliant" weapons (like the A-10) instead of "more complex" weapons (like the B-1 and the F-111) and that quantity had a quality all its own.[69]

Although the Defense Reformers' fight against the complexity, cost, and negative impacts of high tech weapons on force readiness centered mainly on tactical aircraft (TACAIR) and air-to-air combat, their arguments spilled over to precision air-to-ground weapons. Defense Planners (who stood in opposition to the Defense Reformers) saw precision-guided munitions as a revolutionary breakthrough and necessary component of any future military force, frequently citing the Than Hoa bridge in Vietnam to make their case.[70] Reformers, on the other hand, thought precision strike capabilities were

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[66] Futrell, *Ideas, Concepts, Doctrine*, 2, 558.
[67] On the debate between Defense Reformers and Defense Planners in the late 1970's and early 1980's see especially Walter Kross, *Military Reform: The High-Tech Debate in Tactical Air Forces* (Washington, D.C.: National Defense University Press, 1985). See also Shimon Naveh, *In Pursuit of Excellence: The Evolution of Operational Theory* (London: Frank Cass, 1997), 252-256; and Grant T. Hammond, *The Mind of War: John Boyd and American Security* (Washington, D.C.: The Smithsonian Institution Press, 2001), 101-117.
[68] Boyd's collection of briefings were never formally published. The collection can be found on-line at http://www.d-n-i.net/second_level/boyd_military.htm (accessed 18 January 2005). For a recent biography of Boyd, see Robert Coram, *Boyd: The Fighter Pilot Who Changed the Art of War* (New York: Little, Brown, and Co., 2002). For Boyd's role in the Military Reform Movement and an analysis of Boyd's briefings, see Frans Osinga, *Science, Strategy and War: The Strategic Theory of John Boyd* (Delft, Netherlands: Eburon Academic Publishers, 2005), 4-5 and 65-76.
[69] James Fallows, "Muscle-bound Superpower," *The Atlantic Monthly* (October 1979), 61. See also James Fallows, *National Defense* (New York: Vintage Books, 1982).
[70] Kross, *Military Reform*, 103-105.

unproven and exaggerated, and even opposed further development of some new weapons like the improved version of the Maverick with infrared capability. The history of the Gulf War subsequently showed the Reformers to have been technologically short sighted and too quick to dismiss the value of complex weaponry. Still, their positive contributions included a renewed emphasis on maneuver and the offensive in military doctrine, better oversight of weapons development for greater cost-effectiveness, and the generation of vigorous, yet highly politicized, public debate about defense programs and strategies.

In the U.S. Army, the counter-revolution materialized in the new doctrine of "AirLand Battle," a more aggressively counter offensive plan for maneuver warfare.[71] The basic documents of Army doctrine, rewritten in 1975 and 1979, treated air power and limited conflicts in a very brief and generalized way. The 1982 Field Manual 100-5 that promulgated the new AirLand Battle concept, on the other hand, gave air power a prominent (although still supporting) role.[72] AirLand Battle also showed a greater appreciation for the higher order effects of combat, focusing on the operational, rather than the tactical, level of war. Although it was not a joint service development, AirLand Battle was based on the synergies of joint action.[73] AirLand Battle reflected the trend away from the firepower intensive defense toward an offensive effort coordinated between the Army and the Air Force.[74]

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[71] See especially Romjue, "AirLand Battle: The Historical Background," 52-55.
[72] Dennis Drew, "Air Theory, Air Force, And Low Intensity Conflict: A Short Journey to Confusion," in Phillip S. Meilinger, ed., *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell AFB, AL: Air University Press, 1997), 339.
[73] For Air Force perspectives on the Army's AirLand Battle, see James A. Machos, "Air-Land Battles or AirLand Battle?" *Military Review* (July 1983), 33-40; and Thomas A. Cardwell, "One Step Beyond – AirLand Battle, Doctrine Not Dogma," *Military Review* (April 1984), 45- 53.
[74] This perceived need for greater unity of effort between the services was also reflected by the extensive Congressional hearings that culminated in the adoption of the Goldwater-Nichols Act in 1986. See

The most important contribution of the wave of counter-revolution was its impact on the American conception of war. The Army's *AirLand Battle 2000* issued in 1982 (followed by *Air Force 2000*) depicted future battles as more fluid, shorter in duration, and more difficult to control.[75] Key to this transition of conception was the development of operational art. As Shimon Naveh writes, "American military mentality moved from an addiction to attrition based on tactical parochialism and technology to the adoption of operational manoevre."[76] The counter-revolution also involved a rediscovery and resurgence of the nonlinear theory of Clausewitz in the American military, particularly with the 1976 publication of a new edition of *On War* and its subsequent adoption at the war colleges.[77] Overall, the larger currents of the counter-revolution suggested a loosening sense of the orderly battlefield to include a greater appreciation for nonlinearity, emphasis on initiative rather than control, and greater flexibility in military thinking.[78]

There were, however, two weaknesses to the counter-revolutionary movement, especially as it applied to air power. First, the AirLand Battle counter-revolution to the defensive firepower of precision weapons was too closely wed to the ground war to serve as an acceptable schema for the larger, strategically minded Air Force. AirLand Battle's supporting role for air power went against the Air Force's traditional bias toward

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especially James R. Locher III, *Victory on the Potomac* (College Station, TX: Texas A&M University Press, 2002).

[75] Futrell, *Ideas, Concepts, Doctrine*, 2, 566. See *AirLand Battle 2000* (Fort Monroe, VA: Army Training and Doctrine Command, 10 August 1982) and *Air Force 2000: Air University Future Concerns* (Maxwell AFB, AL: Air University, 29 August 1984).

[76] Shimon Naveh, *In Pursuit of Operational Excellence: The Evolution of Operational Theory* (London: Frank Cass Publishers, 1997), 252. See also 257-262 on the impact of the military reform movement.

[77] See Harry G. Summers, Jr., *On Strategy II: A Critical Analysis of the Gulf War* (New York: Dell Publishing, 1992), 126-131. On the continuing relevance of Clausewitz after Vietnam, see also Joe Strange, *Centers of Gravity and Critical Vulnerabilities: Building on the Clausewitzean Foundation So That We Can All Speak the Same Language* (Quantico, VA: Marine Corps War College, 1996), 5.

independence and the centralized control of air assets, pitting the Army's desire to decentralize air power to facilitate ground maneuver against the Air Force's fear of the fragmentation of air power. Understandings of the "operational level" of war differed between the Army and the Air Force. While the Army focused on the corps level and enemy forces that were no more than 30-50 miles from the Forward Line of Troops (FLOT), the Air Force (and NATO) looked to range the entire theater for targets.[79] The reaction of the Air Force to what some saw as Tactical Air Command's surrender to the doctrine of the Army was a renewed search for a plan for air power built around the new technological capabilities, but with a more independent strategic impact.

The second weakness, as noted above, was that counter-revolutionaries underestimated the importance of technological developments in precision weaponry, developments that answered many of their criticisms. By the high tide of defense spending in the late 1980's, the Air Force had introduced new avionics and weaponry that made up for key deficiencies in the ability to detect, attack, and destroy hard mobile targets at night and in bad weather, the very deficiencies identified by Tactical Air Command in 1979.[80] The drastic improvements in the effectiveness of precision munitions weakened the case of the Defense Reformers. But because the new technologies continued to be exceedingly expensive, their criticisms, although blunted, still carried significant weight. In fact, as technology became more user friendly, more capable (especially at night and in the weather), and more compatible across platforms, the new weapons bridged the differences between Defense Planners and Reformers. By

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[78] Wayne M. Hall, "A Theoretical Perspective of AirLand Battle Doctrine," *Military Review* (March 1986), 32-43. See also Osinga, *Science, Strategy, and War*, 65-76.
[79] David R. Mets, *The Long Search for a Surgical Strike: Precision Munitions and the Revolution in Military Affairs* (Maxwell AFB, AL: Air University Press, 2001), 33.

making forces " less vulnerable, more responsive to political control, and possibly less costly... the new technologies of precision guidance," noted Walter Kross, "[provided] a common ground between the political elements in the United States who have been identified as opposing larger defense expenditures and those whose main interests have been in the improvement of U.S. defenses."[81]

DESERT STORM: Putting the Revolution to the Test

The exceptionally one-sided outcome of the 1991 Persian Gulf War confirmed the revolutionary nature of precision air weapons. The war was not only short (a thirty-nine day air campaign followed by a four-day ground battle), but also relatively inexpensive in terms of American lives (only 148 killed during the war and of those, twenty-three percent by friendly fire).[82] Live feeds from CNN of air power's effects on the ground in Baghdad and videos of bombs flying into airshafts reinforced the perception that finding and precisely destroying targets from the air was now a predictable matter of routine. "DESERT STORM was a vindication of the old concept of precision bombing," asserted Air Force Chief of Staff Michael Dugan less than a month after the war's conclusion. "The technology had finally caught up with the doctrine."[83]

The use of precision-guided munitions in DESERT STORM was both quantitatively and qualitatively different than in Vietnam twenty years earlier.[84] In 1991, the United States launched 9,117 aerial strikes that employed 17,109 precision weapons

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[80] Futrell, *Ideas, Concepts, Doctrine*, 2, 558.
[81] Dudzinsky and Digby, *Qualitative Constraints on Conventional Armaments*, xv.
[82] Jeffrey Record, *Hollow Victory: A Contrary View of the Gulf War* (Washington, D.C.: Brassey's (US), Inc., 1993), 6.
[83] Michael Dugan, "First Lessons of Victory," *US News and World Report* (18 March 1991), 36. Quoted in Clodfelter, "Vietnam's Impact," 310.

during the war.[85] Although laser-guided bombs were not new, the Coalition dropped double the number of laser-guided bombs in just six weeks than in the nine months of the LINEBACKER campaigns and with much greater publicity than in the Vietnam War.[86] Thanks to technological improvements in the weapons themselves and the enabling complex of stealth, command and control, and information technologies, the use of smart bombs in DESERT STORM was also qualitatively different, with guided weapons being used primarily at night against a much wider array of targets. And they were also more accurate – 79% of bombs from F-117's fell within ten feet of their aim point.[87]

Although the original intent had been to reserve smart bombs for strategic targets deep in the enemy rear, laser-guided weapons proved especially effective during DESERT STORM for destroying enemy armor and artillery.[88] During a test flight on 5 February, F-111 crews found that they could easily identify and target Iraqi vehicles against the colder desert floor using PAVE TACK infrared targeting pods.[89] General Horner, in charge of the air war, thereafter assigned both F-111F's and F-15E's loaded with five hundred pound GBU-12 laser-guided bombs (which accounted for fifty percent of the guided bombs dropped by U.S. forces) to "tank plinking" against Iraqi ground forces.[90] This method was also cost effective; although the $9000 GBU-12 was more expensive than conventional dumb bombs, it was nevertheless cheaper than the Maverick, Hellfire, or TOW anti-tank missiles. In Vietnam, laser-guided weapons

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[84] *GWAPS, Vol. II, Part 2, Effects and Effectiveness*, 354-355; Thompson, *To Hanoi and Back*, 282-284; and Luttwak, "Air Power in US Military Strategy," 19-20.
[85] *GWAPS, Vol. V, A Statistical Compendium*, 514; and Luttwak, "Air Power in US Military Strategy," 33-35.
[86] Thomas A. Keaney and Eliot A. Cohen, *A Revolution in Warfare? Air Power in the Persian Gulf* (Annapolis, MD: Naval Institute Press, 1995), 203. See also Thompson, *To Hanoi and Back*, 219.
[87] Hallion, *Storm Over Iraq*, 177.
[88] Murray, *Air War in the Persian Gulf*, 321.
[89] *GWAPS, Vol. II, Part 2: Effects and Effectiveness*, 35-36.

claimed more than one hundred Soviet-built tanks. By the end of the First Gulf War, F-111's alone flew 664 successful antitank missions, claiming to have destroyed some 1,500 tanks, mechanized vehicles, and artillery pieces.[91]

A showcase for precision weapons, DESERT STORM, however, also demonstrated continuing limits of control over the course of the war's events. Although qualitatively different from previous wars in terms of intensity and effect, the air campaign was neither as predetermined nor as precise as repeatedly broadcast gun camera footage made it appear. Like other military operations throughout history, DESERT STORM was but a unique episode whose outcomes were dependent upon distinct initial conditions and subsequent interactions.[92] While the great majority of air weapons worked like clockwork, the air operation taken as a whole nevertheless fell somewhere in the middle of the spectrum between mechanical clocks and chaotic clouds.

The Department of Defense's summary report on the war noted that one of the most serious shortcomings of the war was the lack of PGM-capable aircraft.[93] Only ten percent of the Coalition's combat aircraft were capable of delivering precision weapons.[94] Although more systems were added to the mix, the target list grew faster than the inventory of precision-capable aircraft to service it. None of the most numerous aircraft, F-16's and British Tornados, had laser-designating systems for delivering precision weapons. In the north, European Command's PROVEN FORCE task force (waging a

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[90] Hallion, *Storm Over Iraq*, 217.
[91] Gillespie, *Precision Guided Munitions*, 181-182 and 205.
[92] See especially Jeffrey Record, "Why the Air War Worked," *Armed Forces Journal International* (April 1991), 44-45.
[93] U.S. Department of Defense, *Conduct of the Persian Gulf War: Final Report to Congress* (Washington, D.C.: Government Printing Office, 1992), 179-180.
[94] Early plans called for F-111Ds from Tactical Air Command that lacked precision bombing capability; only after planners urged a switch to facilitate precision bombing did the air effort get F-111Fs from European Command. Putney, *Airpower Advantage*, 44 and 121.

semi-autonomous campaign in Iraq above the thirty-fifth parallel from Incirlik Air Base in Turkey) had only F-111E's and F-16's that lacked precision bombing capabilities.[95]

The vast majority of the bombs dropped during the war were in fact unguided. Less than five percent of bombs delivered used precision guidance.[96] Although this smaller proportion of precision weapons claimed as much as seventy-five percent of the damage inflicted on Iraqi targets, area bombing still played a significant role, both in attacking troop concentrations in the Kuwaiti Theater of Operations in the south and also in leveling Iraqi military infrastructure just outside of Baghdad. In one instance during the last two weeks of the war, some seventy B-52's dropped over 3000 bombs on the Taji industrial complex on the northern outskirts of Baghdad in response to Brigadier General Buster Glosson's command to leave nothing standing "taller than a taxi light."[97] Success in the air war went beyond the discriminating effects of precision weapons.

The lack of precise information also limited the precision of the campaign. General Glosson later identified the dearth of adequate intelligence as his number one problem as head of the air planning cell.[98] Available intelligence databases on Iraq were out of date and incomplete. Many of the installation file records on specific targets lacked details on construction, function, and military significance. Furthermore, there was a lack of imagery for 128 of the 218 potential targets initially identified and imagery that did exist was outdated.[99] Forced to "reach back" to intelligence sources in the United

[95] Thompson, "After Al Firdos," 56-61.
[96] Keaney and Cohen, *Revolution in Warfare*, 191 and 280. Dumb "iron" bombs accounted for more than ninety percent of the total tonnage dropped. Luttwak, "Air Power in US Military Strategy," 20.
[97] Wayne W. Thompson, "After Al Firdos: The Last Two Weeks of Strategic Bombing in DESERT STORM," *Air Power History* (Summer 1996), 60-61.
[98] Glosson, *War with Iraq*, 33.
[99] *GWAPS, Vol. 1: Planning*, 194.

States, analysts and planners lacked the computing power, connectivity, and bandwidth required to transmit and receive the voluminous data.[100]

Beyond the deficiency of means, there were also organizational and bureaucratic roadblocks standing in the way of precision intelligence. The CENTAF (the Air Force component of Central Command or CENTCOM) intelligence staff was understaffed and poorly trained for offensive air warfare. Battle damage assessment was in particular, according to Glosson, "haphazard with rules that kept changing." [101] Intelligence analysts trained to measure physical destruction had a difficult time assessing the functional effects of bombing in accordance with new bomb capabilities and air strategies.[102] General Glosson's illicit contacts with Colonel John Warden's CHECKMATE planning cell in Washington generated divisions and dysfunctions within the CENTAF staff.[103] As a result of intelligence shortcomings, air planners underestimated the scope of Iraq's WMD program (which only became apparent after the war) and were never able to solve the problem of finding mobile SCUD launchers in the western desert. As has always been the case, the effectiveness of air power was contingent on detailed, timely, and accurate information and the ability to correctly assess bombing's cumulative effect.

Analysts, basing their pre-war estimates on easily quantifiable indicators of military strength, overestimated Iraqi capabilities. The Iraqi Army was a conventional force armed with outdated Soviet equipment fighting in desert terrain that played to American technological advantages.[104] The Iraqi Air Force was much less effective than that of North Vietnam and even Iraq's daunting air defenses were never able to offer

[100] Putney, *Airpower Advantage*, 359-360.
[101] Glosson, *War with Iraq*, 185-186.
[102] On the difficulties of bomb damage assessment, see especially *GWAPS, Vol. II, Part 2: Effects and Effectiveness*, 30-47.

much resistance to American precision strikes. Although incompetent, Iraq was nevertheless a reacting opponent that occasionally defied Coalition air power. Targeted by Coalition aircraft, Iraqi commanders moved underground into hardened bunkers impervious to even the most accurate of weapons. Government buildings in Baghdad struck from the air were frequently empty, Iraqi occupants having taken their business to more innocuous locations prior to the bombing campaign. During the last few days of the war, for example, F-117s dropped twenty-one bombs precisely on a vacant building in Baghdad that had once housed the Ba'ath Party headquarters.[105]

The Iraqi air forces' refusal to fly and fight (and lose aircraft as had the *Luftwaffe* during the Combined Bomber Offensive) created a latent threat that compelled Coalition strikes against airfields. Made possible by the capabilities of laser-guided bombs, these strikes devolved into a campaign of shelter plinking.[106] To further foil Coalition war plans, Iraq launched SCUD missiles at Saudi Arabia and Israel, demonstrating the political power of even the most imprecise weapons while creating additional operational tasks for Coalition air power.[107] Iraq also took advantage of American hypersensitivity to collateral damage by parking high value equipment by religious and cultural sites and then using CNN's Peter Arnett as a mouthpiece to broadcast the claim that American aircraft had maliciously destroyed a baby milk factory. Even DESERT STORM, where

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[103] *GWAPS, Vol I, Part 2: Planning and Control*, 289-295. Putney, *Airpower Advantage*, 359-360.
[104] Record, *Hollow Victory*, 2.
[105] William M. Arkin, "Baghdad: The Urban Sanctuary in DESERT STORM?" *Airpower Journal* 11/1 (Spring 1997), 16-17.
[106] Whatever the successes of this campaign, precision weapons could have been used to greater effect against other strategic targets. See *GWAPS, Vol. II, Part 1: Operations*, 193-196; and Murray, *Air War in the Persian Gulf*, 201 and 317.
[107] All told, finding SCUD launchers took up fifteen percent of Coalition aircraft missions. Gene I. Rochlin and Chris C. Demchak, "The Gulf War: Technological and Organizational Implications," *Survival* 33/3 (May/June 1991), 265. On the effects of the SCUD hunt on the air campaign, see *GWAPS, Vol. II, Part 1: Operations*, 179-191.

the Coalition overmatched their Iraqi opponents, was a Clausewitzean *zweikampf* waged against an enemy who reacted.

Much of the conduct of the war, to include the use of precision-guided munitions, was ad hoc, the result of adaptation throughout the campaign.[108] The unique character of the war was defined by the cycle of coevolution as Iraqi reaction was met with Coalition counter reaction. To destroy hardened and deeply buried Iraqi command and control targets, engineers at Eglin Air Force Base developed a 4700-pound bomb made from surplus artillery barrels matched to existing PAVEWAY III guidance systems. Two of these GBU-28 penetrating bombs were dropped on 27 February from F-111's on an Iraqi command and control bunker, demonstrating (as airmen had rediscovered bombing bridges in Vietnam) that the size of the bomb was just as important as accuracy in creating the right effects.[109] In another example of adaptation in the air campaign, when Saddam resorted to dumping oil into the Persian Gulf to contaminate Saudi desalination facilities, F-111s used laser-guided bombs to destroy two manifolds on an upstream oil pipeline to stem the flow of oil.[110]

Despite qualitative improvements since Vietnam, laser-guided bombing still required clear weather. Rules of engagement that required visual identification before weapons release reinforced this requirement.[111] Although not nearly as bad as in Vietnam, weather in Iraq in January and February 1991 was the worst in fourteen years

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[108] On the unplanned nature of the employment of laser-guided bombs, see especially Keaney and Cohen, *Revolution in Warfare?*, 192.
[109] Another two bombs had also been produced and expended in testing. John D. Morrocco and David A. Fulghum, "USAF Developed 4,700 lb Bomb in Crash Program to Attack Iraqi Military Leaders in Hardened Bunkers," *Aviation Week and Space Technology*, 6 May 1991, 67. See also Fox, *Precision Guided Munitions*, 7; and Gillespie, *Precision Guided Munitions*, 206-207. On the matching of bombs to bridges, see *GWAPS, Vol. II, Part 2: Effects and Effectiveness*, 352.
[110] Gillespie, *Precision Guided Munitions*, 204. Hallion, *Storm Over Iraq*, 231.
[111] Hallion, *Storm Over Iraq*, 176-177.

and certainly worse than planners expected. On the night of January 18/19, nearly two of every three planned F-117 sorties either missed their targets or did not drop their bombs because of weather.[112] Oil fires in the south also contributed to limited visibility, often creating instrument flying conditions. Some forty percent of the attack sorties scheduled for the first ten days were cancelled because of poor visibility or low overcast in the Kuwaiti Theater of Operations.[113] By the tenth day of the air war, Coalition air forces were still on their fifth day of tasks because of the bad weather.[114] In one four-day period at the height of the SCUD hunt (where visual conditions were required to identify mobile launchers), weather permitted only thirteen effective sorties. Precision air power, then, was still subject to what Edward Luttwak has called its "situational" limits.[115]

DESERT STORM also saw its share of chance events – events that were "effectively random" – that influenced the course of the war. Because of the technical capabilities of weapons and the care and caution air planners, collateral damage and civilian casualties were comparatively low – only 2,300 dead by Iraqi count despite the intensity of air operations.[116] The Coalition largely avoided Iraqi population centers – the general population, in fact, considered Baghdad a safe haven during daylight hours. In forty-three days of war the Coalition dropped only 330 weapons on downtown Baghdad – 244 laser-guided bombs and 86 cruise missiles (only three percent of the precision-guided

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[112] Throughout the war, the F-117 lost approximately twenty percent of its capabilities to weather restrictions alone. Mark E. Streblin, *Targeting for Effect: Is There an Iceberg Ahead?* (Maxwell AFB, AL: Air War College, April 1997), 38. Of the 167 laser-guided bombs dropped on the first five nights of the war, seventy-six missed their targets because of pilot error, mechanical or electronic malfunctions, or poor weather. Rick Atkinson, *Crusade: The Untold Story of the Persian Gulf War* (Boston: Houghton Mifflin Co., 1993), 160.

[113] Coyne, *Airpower in the Gulf*, 90.

[114] Williamson Murray, *Air War in the Persian Gulf* (Baltimore: The Nautical and Aviation Publishing Company of America, 1995), iii.

[115] Luttwak, "Air Power in US Military Strategy," 23.

[116] Keaney and Cohen, *Revolution in Warfare?*, 214. Record, *Hollow Victory*, 112.

munitions expended).[117] After the war peace activists found that the civilian areas of the Baghdad remained entirely intact.[118]

Yet despite these precautions there were a few seemingly unavoidable miscues, some the result of imperfect knowledge, others the result of technical malfunctions. As the Gulf War Air Power Survey wryly noted about the SCUD hunt in the western desert, "It does appear that a number of tanker trucks on the way to Jordan or Basra paid a severe price for having infrared signatures resembling mobile launchers; some Bedouins also may have paid a similar price for having elongated, heated tents in the desert blackness that looked like canvas-draped Scuds."[119] Several attacks on bridges in and around urban areas, which analysts thought sheltered key communication cables, also resulted in civilian casualties; in one incident, a bomb missed a bridge and tumbled into a civilian medical clinic.[120]

The most important political blowback, however, came not from misses, but from a direct hit that was a near textbook case of Charles Perrow's "normal accident." On 13 February, just as the air campaign was refocusing on leadership and political targets in Baghdad, two 2000-pound guided bombs destroyed a command and control bunker at Al Firdos, killing three hundred civilians sheltering inside.[121] CNN reported the incident that morning and the Iraqi government exploited the error by allowing the international media to distribute graphic images of the bunker. After Al Firdos, Washington placed tighter controls on the air campaign; thereafter, targets in downtown Baghdad required

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[117] Arkin, "Baghdad: The Urban Sanctuary," 5-6.
[118] Keaney and Cohen, *Summary Report*, 249.
[119] *GWAPS, Vol. II, Part 1: Operations*, 189.
[120] Thompson, "After Al Firdos," 52-53.
[121] Rick Atkinson, *Crusade: The Untold Story of the Persian Gulf War* (Boston: Houghton Mifflin Co., 1993), 286-296.

Schwartzkopf's direct approval.[122] In the two weeks before the strike, F-117s bombed twenty-five targets in Baghdad. In the two weeks after, they bombed only five.[123] "Al Firdos," Glosson later remarked, "was the nail in the coffin for the strategic campaign."[124]

The air effort was thus in many ways a victim of its own success – the demonstrated ability to precisely destroy targets without civilian damage only raised the bar of expectations. One important upshot of the campaign, a direct result of the "revolutionary" effectiveness of precision-guided weapons in DESERT STORM and the reaction to incidents like Al Firdos, was the emergence of a new norm of sensitivity to casualties (both friendly and enemy) and collateral damage, a norm demonstrated in Somalia and later in the Balkans by the remarkable lengths to which the American military would go to avoid them.[125]

Although the eventual outcome was never in doubt, the course and character of the war were not predetermined. Because of unavoidable necessities – the political necessities of hunting SCUD missiles and weapons of mass destruction and the operational necessity of supporting the ground campaign – the actual air operation bore only faint resemblance to original plans. Air Force planners had estimated that the phased operation against strategic targets, for air supremacy, and then the destruction of ground forces would take less than two weeks; in reality the successful air campaign lasted a total of thirty-nine days, nearly three times that length.[126] The original target list developed by CHECKMATE expanded first from 84 to 200 and then to more than 400

[122] Keaney and Cohen, *Revolution in Warfare?*, 58-59. Murray, *Air War in the Persian Gulf*, 189-191.
[123] Keaney and Cohen, *Revolution in Warfare?*, 185.
[124] Glosson, *War with Iraq*, 228.
[125] Keaney and Cohen, *Revolution in Warfare*, 214-215.

targets; eventually more than 1200 targets made the master attack plan. In the end, only two percent of strategic attacks were against the "leadership" targets in downtown Baghdad that planners had described as the key to the collapse of the Iraqi system.[127]

At the strategic level, the Coalition had successfully driven Iraqi forces from Kuwait. Despite the nearly ideal circumstances of the war, however, several other strategic tasks remained unfulfilled – although weakened, the repressive Iraqi military and political system remained intact; Iraq's SCUD missile capability was not disabled; and the nuclear, biological, and chemical weapons infrastructure had not been dismantled. While blaming these strategic misses on air power alone would be unfair, these were tasks both explicitly and implicitly linked to the new capabilities of precision air power. Despite the superior performance of weapons, translating tactical brilliance into specific strategic outcomes proved just as difficult as ever.[128] Perhaps the most important lesson of the air war was (as the Gulf War Air Power Survey concluded) that limits to the strategic effects of air power "should probably be construed as inherent features of strategic campaigns, not as aberrations or shortcomings that improved weaponry or other technical advances will overcome."[129]

Interpreting the Results of DESERT STORM

In the years following DESERT STORM, air theorists looked to explain and codify the contributions of air power to the one-sided outcome of the war. From this search emerged two important thinkers and three big ideas. The air power thinkers were

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[126] On expectations for the duration of the air campaign, see Putney, *Airpower Advantage*, 360-362.
[127] Budiansky, *Air Power*, 417-418.
[128] See especially Stephen T. Ganyard, "Strategic Bombing Didn't Work," *U.S. Naval Institute Proceedings* (August 1995), 31-35.

John Warden and David Deptula, both key figures in the design of the DESERT STORM air campaign. The three ideas, each tied in some way to Warden and Deptula, were *the enemy as a system*, *parallel warfare*, and *effects-based operations*. None of these ideas was conceived *ex novo* – each was in essence a recurring theme in American air power, newly enabled and brought to the fore by precision weapons and their performance in DESERT STORM.

Colonel John Warden's book, *The Air Campaign*, written in 1988 while a student at the National War College, was one of the first attempts at a more comprehensive air strategy that embraced the new air power capabilities.[130] The book was a turn away from the historical tendency of airmen to focus on the tactical and technological and (as part of the ongoing reaction to the primacy of the defense) a return to the advocacy of the strategic offensive in air warfare. "This book," Warden warned air power technicians, "is not about tactics and does not address how to bomb a target."[131] Although he claimed to focus on the *operational* level of air warfare, Warden conflated the operational with the strategic, discussing both as the process of matching military means to political ends. Warden's focus was on the strategic *offensive*; given the mobility and speed of air power, taking the offensive was "a positive measure that will lead to positive results" – gaining and maintaining the initiative, forcing the enemy to react, and maximizing the use of air assets.[132] The pendulum of air power theory had swung from a mechanical emphasis on defensive firepower, through AirLand Battle's call for supporting the Army offensive, to

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[129] *GWAPS, Vol. II, Part 2: Effects and Effectiveness*, 363-364.
[130] John A. Warden, III, *The Air Campaign: Planning for Combat* (Washington, D.C.: Brassey's, 1989). An earlier, but somewhat less influential, work on the complexities of air power strategy was Barry D. Watts, *The Foundations of U.S. Air Force Doctrine: The Problem of Friction in War* (Washington, D.C.: U.S. Government Printing Office, 1984).
[131] Warden, *The Air Campaign*, xv.
[132] Warden, *The Air Campaign*, 23 and 57.

a theory advocating the independent strategic potential of air power reminiscent of the ideas at the Air Corps Tactical School and more in line with the culture and traditions of the Air Force.[133]

But whereas Air Corps Tactical School theory of the 1930's raced ahead of the technological capabilities of the day, Warden's theory exploited established capabilities for precision bombing. Warden's advantage over the Tactical School was that American air power now had precision weapons that actually worked.[134] By taking advantage of the new weapons, Warden felt airmen could achieve the aspirations of the earliest American air theorists – "the idea of defeating the enemy by striking decisive blows."[135]

For Warden, "All bombing is precision bombing," aimed at the critical vulnerabilities within an enemy system.[136] Where Billy Mitchell and other interwar theorists talked about "vital centers," Warden substituted Clausewitzean "centers of gravity" as the aim point for aerial strikes.[137] Unlike Clausewitz, who described a single center of gravity as "the hub of all power and movement, on which everything depends," Warden allowed for multiple centers of gravity at each level of warfare.[138] This deviation from the strictly mechanical meaning of the term demonstrated a subtle, although perhaps

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[133] See especially Scott D. West, *Warden and the Air Corps Tactical School: Déjà vu?* (Maxwell AFB, AL: Air University Press, October 1999). ACTS theorists and WWII planners would have been quite comfortable with Warden's preferred targets: "Systems exist that support both enemy land and air operations. Their precise identity will vary from war to war. But for the foreseeable future, the petroleum net will be a strong candidate, as will the transportation net…." Warden, *The Air Campaign*, 135.
[134] West, *Warden and The Air Corps Tactical School*, 33. David R. Mets, *The Air Campaign: John Warden and the Classical Airpower Theorists* (Maxwell AFB, AL: Air University Press, 1998), 59.
[135] Warden, *The Air Campaign*, 7. Warden predicted that technological improvements after Vietnam might in fact portend the fulfillment of the visions of Douhet and Mitchell – an "air only" decision in warfare under certain conditions. *Ibid.*, 39.
[136] Warden quoted in Luttwak, "Air Power in US Military Strategy," 28.
[137] Mark Clodfelter, "Solidifying the Foundation: Vietnam's Impact on the Basic Doctrine of the US Air Force," in Sebastian Cox and Peter Gray, eds., *Air Power History: Turning Points From Kitty Hawk to Kosovo* (London: Frank Cass, 2001), 308-311.
[138] Warden, *The Air Campaign*, 7.

subconscious, awareness of the inadequacy of mechanical metaphors in describing the organic complexities of air power.[139]

Although only hinted at in *The Air Campaign*, Warden's post-Gulf War article "The Enemy as a System" captured the holistic nature of his air strategy.[140] As early as the fall of 1988 while serving on the Air Staff, Warden diagrammed the enemy system as an interrelated and interdependent whole made up of five concentric, strategic rings. The most important of Warden's rings – leadership – lay at the center; of decreasing importance beyond the leadership nucleus were key production facilities, infrastructure, the civilian populace, and finally, fielded military forces. Within each ring was a center of gravity, a nexus of linkages that Warden described as "a point against which a level of effort, such as a push, will accomplish more than that same level of effort could accomplish if applied elsewhere." Precision air power, by striking these points, could achieve nonlinear effects, that is, effects out of proportion strategically to the tactical effort expended, without having to destroy the entire system in detail.

Although Warden's work showed insight into the nonlinearity of air warfare, it nevertheless repeated many of the mechanistic tendencies of earlier theories and theorists, both in method as well as in substance. Warden's approach was reductionist. "Because [air warfare] is so complex," he wrote, "it must be broken into component parts that can be examined, studied, and used."[141] Warden divided the enemy system into target *sets*, further dividing these *sets* into components and then discrete *elements*.[142] To avoid the inadequacies of this reductionism in addressing war as a complex social construct,

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[139] Timothy G. Murphy, "A Critique of *The Air Campaign*," *Aerospace Power Journal* (Spring 1994).
[140] John A. Warden, III, "The Enemy as a System," *Airpower Journal* 9/1 (Spring 1995). See also Fadok, *John Boyd and John Warden*, 24.

Warden narrowly focused on conventional state-on-state warfare, ignoring more complex political contexts involving non-state actors and protracted insurgent or revolutionary warfare.[143]

Warden's overly simplistic five-ring diagram of the enemy system depicted opponents as passive constructs that did not react and adapt to aerial attack.[144] Warden considered human behavior less predictable than the effects of physical destruction, so his air theory consequently centered on the targeting of material capabilities.[145] According to Warden, although the new capabilities of air power were revolutionary, modern weapons did not invalidate historical experience that showed success in air warfare as a function of quantitative advantage.[146] Even with precision weapons, Warden wrote, there was still a need to physically mass air power: "True, a single aircraft with a guided weapon can take out a point target, such as a bridge.... On the other hand, a single aircraft cannot put an airfield, marshaling yard, or other significant military target out of commission; only a mass of aircraft can do that."[147] Although more holistic, Warden committed many of the mistakes of earlier air theorists in his reductionism, his treatment of the enemy as a passive object, and his emphasis on quantitative rather than qualitative aspects of air warfare.

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[141] Warden, *The Air Campaign*, 1. See also Cohen, "Strategic Paralysis: Social Scientists Make Bad Generals;" Fadok, *John Boyd and John Warden*, 27-29; and Ware, "Ware on Warden."
[142] Putney, *Airpower Advantage*, 47.
[143] Drew, "Air Theory, Air Force, and Low Intensity Conflict," 343-344. On the weaknesses of Warden's theory applied to non-state actors, see Richard Szfranski, "Parallel War and Hyperwar: Is Every Want a Weakness?" in Barry R. Schneider and Lawrence E. Grinter, eds., *Battlefield of the Future: 21st Century Warfare Issues* (Maxwell AFB, AL: Air University Press, 1995), 131-132.
[144] See Lewis Ware, "Ware on Warden: Some Observations on the Enemy as a System," *Airpower Journal* (Winter 1995). See also Fadok, *John Boyd and John Warden*, 29.
[145] Mets, *The Air Campaign*, 58-60.
[146] Warden, *The Air Campaign*, 61-63.
[147] Warden, *The Air Campaign*, 58.

DESERT STORM gave Warden's ideas great traction in the Air Force. Colonel Warden's CHECKMATE division at the Air Staff formulated the initial plans for the air war against Iraq (named INSTANT THUNDER in derision of the failed gradualism of ROLLING THUNDER in Vietnam).[148] INSTANT THUNDER's five target categories loosely corresponded with Warden's five rings (but without the clever graphics), but each ring was further subdivided into related categories of targets. Although Warden spent the war stateside after a falling out with General Horner, the Joint Forces Air Component Commander, his plan was carried forward by his subordinate, then Lieutenant Colonel David Deptula, as a foundation for later CENTAF air plans.[149] CHECKMATE also served as both a formal and informal source of information and targeting suggestions for forward-deployed air planners throughout the war, further spreading the influence of Warden's ideas over the conduct of the air war.[150]

Following the success of air power in the Gulf War in 1991, Warden took the position of Commandant of the Air Command and Staff College and his concepts quickly found their way into published Air Force doctrine. The 1992 version of AFM 1-1 *Basic Doctrine of the United States Air Force* echoed his call for strategic attacks against "an enemy's centers of gravity including command elements, war production assets, and supporting infrastructure."[151] Nearly ten years later, his ideas continued to permeate doctrine. Air Force Pamphlet 14-118, *Aerospace Intelligence* dated June 2001 explicitly applied Warden's five-ring model to identify "high value targets," concluding that direct

[148] On Warden's influence over the DESERT SHIELD/DESERT STORM planning process see Diane T. Putney, *Airpower Advantage: Planning the Gulf War Air Campaign* (Washington, D.C.: Air Force History and Museums Program, 2004), 35-133. See also *GWAPS, Vol. 1: Planning*, 83-190.
[149] Putney, *Airpower Advantage*, 122-133; and Budiansky, *Air Power*, 414-416.
[150] *GWAPS, Vol. 1, Part II: Operations*, 179-185.
[151] Air Force Manual 1-1, *Basic Doctrine of the United States Air Force* (Washington, D.C.: Headquarters USAF, March 1992).

attacks on fielded forces represent a "high cost and low payoff strategy."[152] Despite its mechanistic shortcomings (or perhaps because of them), Warden's air power theories, in particular his conception of the enemy as a five-ring system, have had a lasting impact on how the Air Force thinks about air power.

Beyond conceptualizing the enemy as a system, the second big idea to emerge in the Air Force from the Gulf War was the notion of *parallel* or *hyper war*. In contrast with ROLLING THUNDER, the air campaigns in both DESERT STORM and LINEBACKER II were not only more accurate, but also more intense. The gradual escalation of bombing in ROLLING THUNDER gave the North Vietnamese sufficient time to adapt and develop countermeasures; the swift and focused attacks of LINEBACKER II and DESERT STORM, on the other hand, allowed less time for the diminution of bombing's effects.[153] Traditional air campaigns arranged events sequentially – first gaining air superiority and then attacking targets step-by-step, gradually accumulating strategic effects. In parallel warfare, as David Deptula conceptualized, targets could be attacked simultaneously or *in parallel* in what amounts to chronological precision – compressing all events into one moment in time – for maximum shock effect and minimum enemy reaction.[154]

[152] Air Force Pamphlet 14-118, *Aerospace Intelligence: Preparation of the Battlespace* (Washington, DC: Headquarters United States Air Force, 5 June 2001), 36-38 and 178-180. Significantly, this same document included a caveat warning against "the Air Force's historic tendency to regard warfare as little more than an exercise in servicing targets... ignor[ing] the fact that *war is an interactive process*, involving two or more sets of intelligent actors." [italics in the original]
[153] Herman L. Gilster, *The Air War in Southeast Asia: Case Studies of Selected Campaigns* (Maxwell AFB, AL: Air University Press, 1993) 122, 129.
[154] See David A. Deptula, "Parallel Warfare: What Is It? Where Did It Come From? Why Is It Important," in William Head and Earl H. Tilford, Jr., eds., *The Eagle in the Desert: Looking Back on U.S. Involvement in the Persian Gulf War* (Westport, CT: Praeger Publishers, 1996), 127-155. The term parallel war came from the Air Force Directorate of Warfighting Concepts Development (AF/XOXW) at the Pentagon. *Ibid.*, 152, n. 5. The term hyperwar apparently originated in the writings of John Warden.

Precision and stealth were the enabling elements of parallel warfare. "For the first time in the history of nonnuclear warfare," wrote John Warden, "we had the concepts, aircraft and weapons to make parallel attack possible. With the new technologies, we were able to think about attacking Iraq as a system, in parallel instead of in the serial fashion, which old era weapons would have dictated."[155] Air power dropped about one hundred thousand tons of bombs on Iraq and Kuwait in six weeks at about the same delivery rate as in World War II, Korea, and Vietnam.[156] What was different from earlier wars was that six weeks of bombing was all that was needed to win the war. With more accurate weapons, air power destroyed objects on the ground more quickly, without having to mass aircraft or repeatedly revisit targets as in the Combined Bomber Offensive in World War II. Precision-guided weapons, theorists claimed, had therefore modified the age-old military principle of massing forces at the decisive geographical point, allowing instead for the massing of *effects* at a given point in time.[157] Stealthy aircraft like the F-117, by negating the historical trend toward increasingly lethal ground-to-air defenses, further enabled parallel warfare by improving delivery accuracy and reducing the number of aircraft needed in force protection packages. The synergistic combination of precision weapons and stealthy aircraft opened new options for American air power.

Parallel warfare, John Warden contended, could thus eliminate the action-reaction cycle that so frustrates combat operations. "The whole business of action and reaction, culminating points, friction, et cetera, was a function of serial war and the imprecision of weapons… [These ideas] are an accurate description of the way things were, but not a

[155] Warden, "Success in Modern War," 187.
[156] Thompson, *To Hanoi and Back*, 284.

description of how they ought to be or can be."[158] The notion of eliminating the time lag between action and effect had occurred to earlier air theorists. Planners gauging the strategic effects of air power prior to the invasion of Europe wrote: "[T]he time of land invasion must coincide with, not precede, the time of full effect of the bombing program. ...Given enough time, the enemy can recover from anything. This brings up the desireability (sic), in fact necessity, for destroying all selected targets within a specified target system in a short time."[159] The idea itself was therefore not new to air power. What was new was the technological potential to make it happen.

Although technology had dramatically accelerated the timelines of cause and effect in war from World War II to DESERT STORM, precluding the action-reaction cycle by condensing the innumerable actions of war was nevertheless a chimerical objective. "War," as Clausewitz noted, "does not consist of a single short blow. ...[A]s soon as preparations for a war begin, the world of reality takes over from the world of abstract thought; material calculations take the place of hypothetical extremes and, if for no other reason, the interaction of the two sides tends to fall short of maximum effort."[160] What was true in the Napoleonic era remained true in the age of information. Air attacks in DESERT STORM, despite the appearance of simultaneity, occurred sequentially and over time; certain objectives like the destruction of command and control nodes were contingent on the success of other actions, most notably the defeat of air defenses and

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[157] See Edward Mann, "One Target, One Bomb: Is the Principle of Mass Dead?" *Airpower Journal* 7/1 (Spring 1993), 35-43; and Mets, *The Air Campaign*, 63. For one of the first doctrinal appearances of this idea, see also *Joint Vision 2020* (Washington, D.C.: Department of Defense, 1996), 17-18.
[158] John Warden interview quoted in Fadok, *John Boyd and John Warden*, 29.
[159] Notes accompanying drafts of FM 100-20: *Command and Employment of Air Power*, 1943, 4. AFHRA file no. 248.211-1.
[160] Carl von Clausewitz, *On War*, Michael Howard and Peter Paret, eds. and trans. (Princeton: Princeton University Press, 1976), 79.

gaining air superiority.[161] The theoretical extreme of parallel or hyper warfare, although appealing, was at the time of the Gulf War still only a goal for the future.

War is a social interaction between human beings that are autopoietic – struggling to define and preserve themselves – and not between objects or machines.[162] An opponent, while trying to paralyze our system through his own devices, will act in ways to avoid our paralyzing blows. Given that absolute simultaneity is impossible, there will be intervening time during which the enemy can react. Because of this interval between action and effects, ultimate effects will often turn out differently than desired. To give but one example from the Gulf War, the Iraqis reacted to Coalition air attacks by launching eight SCUD missiles in a half-hour period the following morning. This reaction introduced new operational and political considerations that changed the character and course of the air war, diverting air resources from the strategic campaign to SCUD hunting in the western desert.[163]

The third big idea to take hold in the 1990s was *effects-based operations*. There were still simply too many worthwhile targets to be destroyed simultaneously despite the new technological capabilities, especially given the scarcity of stealthy, precision-capable aircraft.[164] Rather than concentrating on individual target damage, air planners during the Gulf War instead thought in terms of desired functional *effects* on the enemy system under attack.[165] Focusing on functional effects was a matter of efficiency – more systems could be neutralized using fewer aircraft. It might take many bombs to entirely destroy a large building housing a command and control element; on the other hand, a nearby

[161] See Richard Szafranski, "Parallel War: Promise and Problems," *U.S. Naval Institute Proceedings* (August 1995): 59.
[162] Szfranski, "Parallel War: Promise and Problems," 59.
[163] *GWAPS, Vol. II, Part 1: Operations*, 184-191.

weapons impact could persuade personnel to abandon their facility to seek shelter and achieve the same overall effect. Effects-based operations, much like the "industrial web" philosophy of ACTS, was thus a positively nonlinear strategy – one that could create maximum output for a disproportionately small input. The Gulf War Air Power Survey's study of effects versus effectiveness in 1993 helped to institutionalize the notion of effects-based operations.[166] By 1997, effects-based ops was firmly planted in Air Force basic doctrine.[167]

Most simply stated, effects-based operations measured success in terms of "effective control" over enemy actions rather than by their physical destruction; its targeting methodology fit well with the American proclivity for efficiency not only because it maximized scarce resources, but also because the functional destruction it advocated was potentially more discriminate than physical destruction.[168] The best (and most frequently used) example of the benefits of this targeting strategy is the disruption of the Iraqi integrated air defense system during DESERT STORM. Rather than targeting each individual gun or radar for destruction, planners deduced that just one well-placed bomb would discourage Iraqis from manning their weapons and radars, effectively neutralizing nodes within the air defense network. In the event, this method

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[164] Putney, *Airpower Advantage*, 161-165.
[165] Keaney and Cohen, *Revolution in Warfare?*, 203-204. See also Glosson, *War With Iraq*, 153-159.
[166] *GWAPS, Vol. II, Part 2: Effects and Effectiveness*, especially 48-57.
[167] *Air Force Basic Doctrine Document 1* (Washington, D.C.: Headquarters Air Force, September 1997), 24 and 30. On the increasing influence of effects-based operations in American air power, see also Brett T. Williams, *Effects-Based Operations: Theory, Application and the Role of Air Power* (Carlisle Barracks, PA: US Army War College, April 2002). For the potential implications of effects-based operations for the U.S. military, see *Joint Warfighting Center Pamphlet 7: Operational Implications of Effects-based Operations (EBO)* (Norfolk, VA: United States Joint Forces Command, 17 November 2004).
[168] Deptula, *Effects-Based Operations*, 6; Deptula, What is Parallel Warfare?," 138-141; and David A. Deptula, "Firing for Effects." *Air Force Magazine* (April 2001), 46-53.

of targeting used only a fourth of the resources originally planned for each target yet caused a near total collapse of Iraq's air defense network.[169]

Although thinking about air power in terms of effects is potentially more efficient, it doesn't make war inherently more rational. Higher order effects – those that accumulate and cascade over time across the levels of war – are contingent and nonlinear and therefore not easy to predict. As current Air Force doctrine notes, "The challenge in assessing operational and strategic effects is the difficulty in accurately linking specific actions to outcomes due to the hard to quantify variables like public opinion, political decisions, and leader personality. ...[T]he time delay factor and the number and variety of cascading and cumulative effects all occurring simultaneously combine to create a complex web of effects."[170] Unraveling this web of effects to get at the desired effect can, as the Gulf War demonstrated, be a difficult proposition.[171]

Military planners in the Gulf War inadequately anticipated many of the higher order consequences of bombing. Cutting communications links between Baghdad and the front lines not only failed to paralyze the Iraqi military, but also may have unnecessarily prolonged the withdrawal from Kuwait by keeping political leaders in the dark about the state of their military forces. Coalition pilots efficiently destroyed the Iraqi electrical system, but shutting down electricity also shut down air conditioning, refrigeration, water purification and sewage treatment plants. Destroying more easily distinguished, but more difficult to repair, generators instead of transformers, switching yards, or control buildings complicated restoration of the electrical system after the

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[169] Phillip S. Meilinger, "Air Warfare: An Historical Perspective," in Christopher Finn, ed., *Effects Based Warfare* (London: The Stationery Office, 2003), 75.
[170] *United States Air Force Doctrine Watch #14* (Maxwell AFB, AL: Headquarters, United States Air Force Doctrine Center, 16 February 2001), 1.

war.[172] Combined with post-war economic sanctions and Saddam's callousness toward his population, turning off the electric grid for a prolonged period of time increased civilian suffering and deaths.[173] As the Gulf War Air Power Survey concluded in response to these charges, "...war is not an engineering enterprise whose results can be calculated in advance. Faulting the commanders and planners who ran this portion of the air campaign for 'overkill' not only ignores this essential point but, in addition, demands of them an impossible degree of predictive foresight regarding the second-order or unintended consequences of military operations."[174]

The difficulties of determining ultimate effects gave American air theorists after the "certain victory" of the Gulf War, including both Warden and Deptula, a better appreciation of the inherently uncertain and indeterminate nature of warfare. "War is dynamic," wrote Deptula in a post-war explanation of parallel warfare. "No theory completely captures all of its operative elements for every situation. As a consequence... any or all of these contingencies may change the calculus of the original parallel attack formula, requiring additional application of force and lengthening the time to achieve desired effects."[175] Even with "perfect" information, the causal relationship between action and effect in war is too complex to decipher precisely which action caused which effect. Although we may aim for certain effects that lead to specific outcomes,

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[171] See especially Gregg Easterbrook, "Operation Desert Shill," *New Republic* (30 September 1991), 40; and Record, *Hollow Victory*, 111-114.
[172] Keaney and Cohen, *Revolution in Warfare*, 61.
[173] See especially Alberto Ascherio, et al., "Effect of the Gulf War on Infant and Child Mortality in Iraq," *The New England Journal of Medicine* 327/13 (24 Sep 1992), 931. See also Putney, *Airpower Advantage*, 352-353; and Thomas E. Griffith, Jr., *Strategic Attack of National Electric Systems* (Maxwell AFB, AL: Air University Press, 1994), 41-42.
[174] *GWAPS, Vol. II, Part 2: Effects and Effectiveness*, 307.
[175] Deptula, "Parallel Warfare," 145.

unintended effects – as the Al Firdos bunker and post-Gulf war mortality rates aptly testify – are always possible.[176]

Dealing in the difficult world of higher order effects also led to a search for new models to better account for uncertainty and nonlinear effects. Up-and-coming air theorists have explicitly applied the new sciences of chaos and complexity theory to analyze past air operations and improve existing theory. In 1995, Steven Rinaldi published a thesis at the Air Force's graduate school for strategists, the School of Advanced Air and Space Studies, applying complexity studies to the study of national economies to improve the effectiveness of economic targeting.[177] Edward Felker, while attending the Air War College, used chaos theory to critique Warden's five rings, building a new model that showed them as linked and interdependent, rather than independent.[178] Another Air Force study applied chaos theory to center of gravity analysis.[179] Nonlinear notions, despite Warden's prewar faith in the linearization of war, had subtly worked their way into American air power theory as it became increasingly

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[176] Edward A. Smith, *Effects Based Operations: Applying Network Centric Warfare in Peace, Crisis, and War* (Washington, D.C.: National Defense University, 2002). See especially Chapter 6, "The Challenge of Complexity," 231-294. See also Barry Watts, "Measuring the Effects of Military Operations," unpublished briefing (January 2002).

[177] Steven M. Rinaldi, *Beyond the Industrial Web: Economic Synergies and Targeting Methodologies* (Maxwell AFB, AL: Air University Press, 1995). See also Stephen M. Rinaldi, "Complexity Theory and Airpower: A New Paradigm for Airpower in the 21st Century," in David S. Alberts and Thomas J. Czerwinski, eds., *Complexity, Global Politics, and National Security* (Washington, D.C.: NDU Press, 1997), 247-302.

[178] Edward J. Felker, *Airpower, Chaos, and Infrastructure: Lords of the Rings* (Maxwell AFB, AL: Air War College, August 1998). Felker concluded that a failure to capitalize on these linkages led to shortcomings in the Gulf air war: "As in prior conflicts, airmen recognized complex interconnections among the elements of a society, but they could not exploit them because the planners did not recognize their interrelationships. The net result of the Instant Thunder plan was that targeting and timing were correct because the identified targets were struck and extensively damaged, but the anticipated end state did not occur because the linkage of targets and aims was missing or at best misguided." *Ibid.*, 29-30.

[179] Pat Pentland, "Center of Gravity Analysis and Chaos Theory," Maxwell AFB, AL: Air War College, April 1993. For other examples of the application of the new sciences in air power theory see also David Nicholls and Todor Tagarev, "What Does Chaos Theory Mean for Warfare?" *Airpower Journal* (Fall 1994), 48-57; and Robert P. Pellegrini, *The Links Between Science and Philosophy and Military Theory:*

holistic and more appreciative of war as a dynamic, uncertain, and irreducible phenomenon.

Conclusion

The transformation of American air power was the result of the combination of effective precision weapons with operational concepts that emerged from the debate over defense reform in the late 1970's and 1980's. The test tube for this combination was the Persian Gulf War in 1991. Although the war demonstrated the truly revolutionary nature of precision weapons, it also showed that this revolution had yet to change the nonlinear nature of war. Despite the over determined nature of the victory, the war still saw its fair share of effectively random events that shaped the nature and course of the war. Contrary to the desires of military planners, tactical proficiency still did not directly translate into control over strategic outcomes.

Three concepts dominated American air power theory after the war – the enemy as a system, parallel war, and effects-based operations. While these ideas showed a greater appreciation for the nonlinearity of war, they repeated much of the reductionism and mechanism of earlier air power theories. Reducing the enemy system to its component parts did little to promote understanding of the emergent characteristics of the system as a whole. Both *the enemy as a system* and *parallel warfare* underestimated the enemy as an adaptive and reacting opponent. Although *effects-based operations* did draw attention to the importance of linking action and its higher order effects, it could do

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Understanding the Past, Implications for the Future (Maxwell AFB, AL: School of Advanced Airpower Studies, June 1995).

little to rationalize and simplify these complex causal chains. The new theories had yet to surmount the challenge of nonlinearity, if only because they still had not entirely overwritten the traditional linear paradigm of analysis, efficiency, and control.

During Operation DELIBERATE FORCE over Bosnia in 1995, the fortuitous combination of precision air strikes with a timely Croat invasion seemed to reaffirm the "lessons" of precision air power from LINEBACKER II and the Gulf War.[180] Success instilled confidence in policy maker and airmen alike in the clout of precision technology, instead of in the ways and circumstances in which the technology was applied. This misplaced confidence guided the use of air power against Serbia in 1999. The air war over Kosovo, rather than reflecting the novel aspects of the new theory, was the product of the traditionally deterministic mindset that embraced weaponeering and the mechanical servicing of target lists. Although aimed in the right direction, air power's transformation remained incomplete.

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[180] See especially Richard P. Hallion, "Precision-Guided Weapons and the New Era of Warfare," *Air Power History* (Fall 1996), 13-14.

Nonlinearity and the Air War Over Kosovo

"The allure of airpower puts a greater responsibility on the Air Force to adapt its capabilities and strategies far beyond what exists or was worked in Operation Desert Storm, the persistent reference point."

General Wesley K. Clark, *Waging Modern War*[1]

Operation ALLIED FORCE, the U.S.-led operation to halt Serbian aggression in Kosovo from March to June 1999, was a war waged solely from the air that relied largely on precision-guided weapons. The 78-day campaign, hailed by Secretary of Defense William Cohen as "the most precise application of air power in history," highlighted weapons technologies developed after DESERT STORM.[2] The new smart bombs, with greater standoff range and all-weather capabilities, outclassed earlier generations of guided air weapons. These improvements, however, did not prevent the occasional stray weapon. With increased expectations for weapons performance, these imperfections carried even greater political and strategic consequence. Success required balancing the political discord from imperfect precision with the benefits the new aerial capabilities could bring.

The debate between airmen and ground soldiers over whether or not Kosovo had proved that air power could go it alone overshadows a more important point: *war's nonlinearity persists despite ever-increasing technological precision in applying coercive force*. Airmen planning the air campaign spoke the language of "effects-based operations," but the negative political objectives of casualty avoidance and collateral

[1] Wesley K. Clark, *Waging Modern War: Bosnia, Kosovo and the Future of Combat* (New York: PublicAffairs, 2001), 430.
[2] Bradley Graham, "Air Power 'Effective, Successful,' Cohen Says," *The Washington Post* (11 June 1999), 1. Quoted in Benjamin S. Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Assessment* (Santa Monica, CA: RAND Corporation, 2001), 219.

damage limitation constrained the application of this theory to the air targeting process. The political and military context of the war was indeed unique; the forces that distorted the course of the air war – the inevitable political constraints and an imperfect targeting process – however, were anything but unique. Precision air power, as in DESERT STORM, did not fail in ALLIED FORCE. Precision-guided weapons, however, were only as good as the strategic and political processes that ultimately guided their use.

Improving Air Power Technologies

Technological developments after DESERT STORM improved the lethality, usability, and standoff capabilities of precision air weapons. The new AGM-142 HAVE NAP was a standoff missile that used an inertial navigation system instead of the weather-dependent laser or electro-optical guidance of the GBU-15. Launched from long-range bombers like the B-52, the AGM-142 weighed 3300 pounds and delivered a 750-pound warhead. The AGM-154 Joint Standoff Weapon (JSOW) was a Navy-designed 1000-pound glide bomb equipped with folding wings that could be launched from fifteen to forty-seven miles away from its target depending on aircraft altitude. The JSOW, first conceived in 1986 but not operational until 1998, delivered either anti-personnel cluster bombs or anti-armor sub-munitions like the deadly BLU-108 sensor-fuzed weapon that dispensed four independent precision-guided projectiles to seek and destroy armored vehicles. Only the "A" model variant of the JSOW carrying munitions designed for "soft" targets was available in 1999. Air Force B-1B bombers did, however, drop the BLU-108 using the wind corrected munitions dispenser (WCMD), a new tail guidance kit for cluster bombs, against Yugoslav armored vehicles in Kosovo.[3]

The most significant new technological capability was terminal guidance from orbiting satellites of the Global Positioning System (GPS). The GBU-31 Joint Direct Attack Munition (JDAM), used inertial guidance supplemented by GPS information (as did the JSOW) that limited inertial drift in flight for an autonomous, all-weather, "launch and leave" capability.[4] Developed out of dissatisfaction with the limitations of laser-guided weaponry in DESERT STORM, the JDAM was a relatively inexpensive $18,000 guidance kit strapped to an existing 2000-pound bomb that could be dropped from as many as fifteen miles from its target. The JDAM provided only "near precision" accuracy with a circular error probable of around thirty feet, not the true precision of the PAVEWAY III laser guidance system, but its all-weather capability more than made up for this deficit.[5] Exceedingly cheap and easy to fit to existing bombs, the GPS-guided JDAM heralded the future ubiquity of aerially-delivered precision weapons; its cost-effectiveness and all-weather capability in effect answered many of the objections to precision weapons raised by the military reformers of the late 1970's.

Like other weapon systems, the JDAM nevertheless had its limits. Airmen needed to know exact coordinates before they could program the bomb to guide to its target – precision bombing was more than ever a function of precision intelligence. Because the JDAM required fixed coordinates, the bomb was not particularly useful

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[3] Michael Russell Rip and James M. Hasik, *The Precision Revolution: GPS and the Future of Aerial Warfare* (Annapolis, MD: Naval Institute Press, 2002), 247.
[4] Stephen Budiansky, *Air Power: The Men, Machines, and Ideas That Revolutionized War, From Kitty Hawk to Gulf War II* (New York: Viking Penguin, 2004), 431-432.
[5] During developmental testing, the JDAM achieved an accuracy of around fifteen feet, bettering its objective of thirty-five feet. Glenn W. Goodman, Jr., "Lethal Lineup: U.S. Air Power Boasts Versatile

against mobile targets (a significant limitation in Kosovo where a major objective was the destruction of mobile ground forces). The weapon, with its introduction in ALLIED FORCE in the spring of 1999, was still in developmental testing and its supply was limited – less than a month into the air war, there were only 609 JDAM kits remaining in the entire Air Force inventory.[6]

The air war over Kosovo also saw the combat debut of the B-2, the only aircraft certified at the time to employ the JDAM. The B-2 is a stealthy, high tech bomber that can fly more than 6,000 miles unrefueled and more than 10,000 miles with just one air refueling while carrying up to sixteen JDAMs in its wings. The combination of the B-2 and the all-weather JDAM added a measure of flexibility to the air campaign – the B-2 was the first aircraft that could transmit target information from the cockpit to its GPS-guided bombs while in flight.[7] Because of the B-2's exorbitant costs, the inventory was limited to twenty-one aircraft at the time of the Kosovo operation. Only nine of these had been upgraded to the final operational configuration. The B-2's cost and scarcity raised the threshold for risking them in combat and, along with complex maintenance requirements, restricted options for basing. B-2's flew thirty-hour missions from Whiteman AFB, Missouri that required multiple air refuelings not because they could, but because they had to. Bombing missions from Whiteman generally required three days of planning, effectively ruling out attacks against anything but well-located fixed targets.[8] The efficiency of the new precision technologies thus paradoxically created

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Array of Precision Air-to-Ground Weapons," *Intelligence, Surveillance & Reconnaissance Journal* (September 2004), 22.

[6] Lambeth, *NATO's Air War for Kosovo*, 170-171. The JDAM did not go into full operational production until two years later in March 2001.

[7] Anthony H. Cordesman, *The Lessons and Non-Lessons of the Air and Missile Campaign in Kosovo* (Washington, D.C.: Center for Strategic and International Studies, 1999), 180.

[8] Rip and Hasik, *The Precision Revolution*, 389.

inefficiencies and potential vulnerabilities, driving airmen toward fixed targets and away from Serbian fielded forces in Kosovo.

Translating Capabilities into Desired Effects

Taking full advantage of the technological improvements since DESERT STORM required translating new capabilities into actions that would provide the desired strategic and political effects. Planners drew a straight line from the successful air coercion of Milosevic during Operation DELIBERATE FORCE to the Kosovo crisis. DELIBERATE FORCE was the NATO air campaign conducted against the Bosnian Serbs between 30 August and 14 September 1995. The Balkan Air Campaign Study, conducted by the Air Force after the war at Air University, observed that "*precision weapons made Deliberate Force possible.* ...Precision weapons gave NATO airmen the ability to conceive and execute a major air campaign that was quick, potent, and unlikely to kill people or destroy property to an extent that would cause world opinion to rise against and terminate the operation." A second observation of the study group was that "NATO's primary reliance on air-delivered weapons... shielded the international intervention in Bosnia from 'mission creep.'" That is, without the exclusive use of precision air power, the Serbs would have had a much greater opportunity to inflict casualties on the NATO contingent, casualties that might have increased political and military uncertainty about the conflict.[9]

The political and operational context of 1999, however, differed from the context of 1995. Serbs considered Kosovo, unlike Bosnia, an integral part of the homeland and were therefore less amenable to military coercion. There was also no immediately threatening ground operation as effective as the fortuitously-timed Croatian offensive that accompanied DELIBERATE FORCE in 1995. The takeaway lesson may have been that air power discriminately and precisely applied had delivered the Dayton Accords. But the more relevant and important operational lessons of DELIBERATE FORCE, eclipsed by Milosevic's quick acquiescence, were that weather was still a constraining factor for air power (weather grounded around a third of U.N. strike sorties) and that finding, following, and destroying mobile targets in the wooded and mountainous terrain of the Balkans was much more difficult than in the open deserts of Iraq and Kuwait.[10] Perhaps a more insightful episode in preparing for Kosovo was the earlier air campaign over Bosnia, Operation DENY FLIGHT, where U.N. political constraints, much like NATO restrictions over Kosovo in 1999, limited U.S. air power, as General Michael Ryan quipped, to little more than "making noise."[11]

The Clinton administration's somewhat ambiguous and amorphous strategic objectives for ALLIED FORCE were: first, to demonstrate NATO's seriousness in opposition to aggression; second, to deter Milosevic from continuing his attacks on Kosovar civilians; and if necessary, to diminish Serbia's capacity to wage war against Kosovo in the future.[12] Overestimating the efficacy of air power while implicitly

[9] Italics in the original. Robert C. Owen, ed. *Deliberate Force: A Case Study in Effective Air Campaigning* (Maxwell AFB, AL: Air University Press, 2000). 507-508. See also John A. Tirpak, "Deliberate Force," *Air Force* 80/10 (October 1997).
[10] Benjamin S. Lambeth, *The Transformation of American Air Power* (Ithaca, NY: Cornell University Press, 2000), 175-176.
[11] Lambeth, *The Transformation of American Air Power*, 179.
[12] President William J. Clinton, televised national address, 24 March 1999. Quoted in T.W. Beagle,Jr., *Effects-Based Targeting: Another Empty Promise?* (Maxwell AFB, AL: Air University Press, 2001), 70. See also *Joint Statement of William S. Cohen, Secretary of Defense and General Henry H. Shelton, Chairman Joint Chiefs of Staff to the Senate Armed Services Committee on Kosovo After-Action Review*, 14 October 1999, 4.

acknowledging the limited resolve of NATO allies, American political leaders publicly ruled out a ground offensive and directed the military to prepare for a brief bombing campaign against a limited set of targets.

The lack of strategic consensus in Washington, not to mention within the NATO alliance, made translating objectives into air targets all the more difficult. Although the military chiefs expressed doubts that bombing alone could achieve desired political objectives, they nevertheless agreed to an air-only campaign.[13] Precision air power was the preferred option not only because it was seen as potentially cost-free, but also because it could be easily controlled.[14] Given the lack of strategic consensus and the short-term, crisis nature of the operation, there was little detailed planning prior to the start of air operations on 24 March 1999.[15] What was settled upon was that the air campaign would be a coercive operation meant to inflict only enough pain on Milosevic to persuade him to submit.[16]

The air campaign was designed as three distinct, yet overlapping, phases. In Phase I, air power was to target and destroy the Serb air defense system, to include airfields, radars, and command facilities, to enable the rest of the bombing campaign. In Phase II, NATO air power would attack Serb forces and facilities to disrupt their actions in Kosovo. Finally, if needed, air power would move to Phase III, attacking political and leadership targets in Belgrade as well as economic infrastructure targets such as oil refineries, electrical stations, and bridges.[17]

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[13] See Bradley Graham, "Joint Chiefs Doubted Air Strategy," *The Washington Post* (5 April 1999), A1.
[14] Clark, *Waging Modern War*, 432.
[15] Clark, *Waging Modern War*, 439. See also Dana Priest, "The Battle Inside Headquarters: Tension Grew With Divide Over Strategy," *The Washington Post* (21 Sep 1999), A1.
[16] Lambeth, *The Transformation of American Air Power*, 183.
[17] Rip and Hasik, *The Precision Revolution*, 385-386.

Military commanders, anticipating a short struggle, entered the campaign with insufficient air forces for sustained operations. NATO began the war with approximately 350 aircraft (of which only eighty were capable of bombing) and not a single aircraft carrier in range of Serbia.[18] As the Joint Forces Air Component Commander (JFACC), Lieutenant General Michael Short, later recalled: "I can't tell you how many times the instruction I got was 'Mike, you're only going to be allowed to bomb two, maybe three nights. That's all Washington can stand. That's all some members of the alliance can stand. That's why you've only got ninety targets. This'll be over in three nights.'"[19] The rapid and unexpected growth of the operation, however, from Secretary of State Madeleine Albright's original call for 2-3 days of bombing into a seventy-eight day campaign involving 38,000 sorties severely strained existing logistical and operational resources.[20]

Disagreements at the operational level about how to translate political objectives into military actions complicated and diluted the air targeting process, making it all the more difficult to get from action to intended effect. General Wesley Clark's role as Supreme Commander of NATO and Commander, U.S. European Command put him closer to the political objective of the mission than his air subordinate, Lieutenant General Short. While Clark was most concerned with maintaining the cohesion of the alliance, Short was determined to apply air power in accord with post-DESERT STORM theory and doctrine for the most immediate operational effect. Clark's "measures of

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[18] Ivo H. Daalder and Michael E. O'Hanlon, *Winning Ugly: NATO's War to Save Kosovo* (Washington, D.C.: Brookings Institution Press, 2000), 103. Rip and Hasik, *The Precision Revolution*, 384.
[19] Interview with Lieutenant General Michael Short, PBS Frontline, "War in Europe," 22 February 2000. Online at http://www.pbs.org /wgbh/pages/frontline/shows/kosovo/interviews/short.html (accessed 8 September 2004).
[20] See especially Michael C. Short, *End of Tour Report: Commander, Sixteenth Air Force and Commander, Allied Air Forces Southern Europe* (Aviano AB, Italy: Office of History, 16 June 2000).

merit" for the campaign – minimizing aircraft losses and collateral damage, protecting NATO ground forces in Bosnia, maintaining alliance solidarity, all while directly impacting Serb forces on the ground in Kosovo as soon as possible – reflected not only his awareness of the political nature of the operation, but also his bias as a ground commander.[21] Clark, obsessed with the Serb Third Army in Kosovo, wanted air power directed against land targets and considered success against Serb ground forces "a political, legal, and moral necessity."[22]

Short, on the other hand, thought the war could be won quickly by taking the fight "downtown" to Milosevic and his regime.[23] Like other airmen educated in the strategic theories of Warden and confident in the new capabilities of stealth and precision weapons, Short believed the most efficient use of air power was against economic and political centers of gravity, rather than against the enemy's fielded forces. Since Milosevic cared little about what happened to the Third Army, Short reasoned, throwing expensive bombs and missiles against smaller, less lucrative ground targets would be less effective than hitting Serbia where it hurts – in the capital Belgrade.[24] The differences between Clark and Short were so pronounced that Clark later complained that the Air Force was deliberately dragging its feet by over-exaggerating the difficulties of weather, with massing aircraft, or with Serb defenses when it came to striking ground targets. Impediments to air power, Clark asserted, "always seemed more troublesome when the

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[21] "I was operating with the starting assumption that there was no single target that was more important, if struck, than the principle of alliance consensus and cohesion." Clark quoted in Priest, "The Battle Inside Headquarters," A1. See also Clark, *Waging Modern War*, 183-184 and 346; John Tirpak, "Short's View of the Air Campaign," *Air Force Magazine* 82/9 (September 1999); and *Air War Over Serbia: Aerospace Power in Operation ALLIED FORCE* (Washington, D.C.: Headquarters, USAF, 2000), 10, 23.
[22] Clark, *Waging Modern War*, 241-242.
[23] See Short interview on PBS Frontline. See also Tirpak, "Short's View of the Air Campaign."
[24] Dana Priest, *The Mission: Waging War and Keeping Peace With America's Military* (New York: W.W. Norton & Co., 2003), 272.

object was to attack the ground forces than when it was to attack the strategic targets."[25] Short, on his part, admitted to putting just enough sorties against Serb forces in Kosovo to satisfy his commander's guidance, "while I used the rest of my assets to attack that target set that I genuinely believed to be compelling."[26]

Although both Clark and Short agreed that air power was best used intensely and unsparingly rather than in penny packets, Clark, as NATO's military commander, was more willing to trade bombing intensity for campaign continuity. Clark's greatest fear, given the fragile nature of support for bombing within the alliance, was that a bombing pause might lead to a cessation of bombing short of success.[27] Having written his master's thesis on the failed gradualism of ROLLING THUNDER in Vietnam, Clark blamed the failure not on the policy of gradualism itself, but on the ways in which air power was gradually administered. "I didn't want to get into something like the Rolling Thunder campaign, pecking away indefinitely. We've got to steadily ratchet up the pressure."[28] Air power was still a force that could be dialed up to the appropriate level of coercion based on an opponent's responses. Modulating the levels of coercive force required Clark's micromanagement; modern communications facilitated this micromanagement of the air campaign. Throughout the course of the operation, Clark conducted some ninety-four video teleconferences with his air commanders, at times suggesting the particular weapon to be used against a target or the precise desired mean point of impact (DMPI) to be hit with the chosen weapon.[29]

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[25] Clark, *Waging Modern War*, 245.
[26] Tirpak, "Short's View of the Air Campaign."
[27] Clark, *Waging Modern War*, 177 and 205.
[28] Priest, *The Mission*, 269.
[29] Lambeth, *NATO's Air War for Kosovo*, 191-192.

The overriding political objective of casualty avoidance further complicated the translation of strategic goals to operational plans and tactical actions.[30] Effects avoidance – avoiding the negative political fallout from casualties – was just as important as achieving positive effects. Clark made this explicit to his airmen: "I told them in no uncertain terms that we were not going in below 15,000 feet, they would be flying only at night and should not make multiple passes or other maneuvers that would entail unnecessary risks."[31] Avoiding unintended civilian casualties was even more important to maintaining the cohesion of the alliance. There were no deliberate attacks on population centers and NATO political authorities, through a long and convoluted process, had to give their approval for every target. Air planners also carefully calculated the effects of weapons on each aim point, applying formulas to estimate collateral damage and unintended civilian casualties, formulas that considered not only the intended target, but also the surrounding area likely to be affected by the bomb's blast.[32] As Short related, "[W]e were restricted by enormous concern for collateral damage and unintended loss of life... [T]hat was the litmus test we used to pick a target."[33] ALLIED FORCE then was not air war in its absolute, but a war severely limited by political considerations and conflicting views about how best to achieve desired objectives.

The two demands of "post-heroic" warfare – avoiding civilian casualties and minimizing risks to pilots – stood in direct contradiction to one another.[34] Applying air power from a distance – lobbing cruise missiles like the CALCM and the Navy's

[30] Tirpak, "Short's View of the Air Campaign." See also *Air War Over Serbia: Aerospace Power in Operation ALLIED FORCE* (Washington, D.C.: Headquarters, USAF, 2000), 10, 23.
[31] Clark quoted in Charles Lyon, *Operation Allied Force: A Lesson on Strategy, Risk, and Tactical Execution* (Washington, D.C.: National Defense University, n.d.), 24.
[32] Clark, *Waging Modern War*, 179.
[33] Tirpak, "Short's View of the Air Campaign."
[34] Michael Ignatieff, *Virtual War: Kosovo and Beyond* (New York: Metropolitan Books, 2000), 62.

Tomahawk land-attack missile (TLAM) from afar and restricting bombers to altitudes above 15,000 feet – came at a price. Standoff bombing increased the likelihood of unintended collateral damage while imposing further complications on the targeting process.[35] The use of cruise missiles and "launch and leave" bombs meant there was no aircrew confirmation of just what the weapon had hit. Cruise missiles, given the time they required to program and that they could not be recalled once launched, allowed for simultaneity but not for flexibility. Despite published cruise missile median accuracies of less than ten feet, the CALCM had a successful launch rate of around seventy-five percent during ALLIED FORCE and a hit rate of less than fifty percent.[36]

Target selection became a mechanical process where targets were chosen based on their distance from civilian dwellings rather than doctrinal prescriptions or even their relation to the objectives of the campaign. Rules of engagement, not effects-based schemes for strategic paralysis through parallel attacks, drove target allocations. Strict control over the air campaign went against the doctrinal principle long cherished by airmen of centralized control – decentralized execution.[37] The constraints of post-heroic warfare also made it nearly impossible to protect persecuted Albanians in Kosovo since small groups of offending Serbs could not be hit by cruise missiles or accurately identified by pilots flying above 15,000 feet. Air Force commanders complained that political measures intended to reduce friendly and enemy casualties in the end "reduced

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[35] Edward N. Luttwak, *Strategy: The Logic of War and Peace* (Cambridge, MA: The Belknap Press of Harvard University Press, 2001), 204.
[36] Cordesman, *Lessons*, 188.
[37] *Air Force Basic Doctrine Document 1* (Washington, D.C.: Headquarters Air Force, September 1997). For several tactical examples see Christopher E. Haave and Phil M. Haun, eds., *A-10's Over Kosovo* (Maxwell AFB, AL: Air University Press, December 2003), 147-153.

mission effectiveness, lengthened the campaign, and put aircrews at greater risk to enemy air defenses over time."[38]

Despite the neat appearances of the phased plan for air operations, in reality there were no clear "objectives" during the first month of the war, only a series of politically approved targets. Expectations for a short war and the complicated approval process precluded a smoothly running system for aerial strategy and targeting until almost the end of April. Airmen in the Combined Air Operations Center in Vicenza, Italy concentrated on the daily production of the air tasking order, on servicing targets, with little regard for objectives, much less effects.[39] The impression of one combat squadron commander during the war was "We were merely blowing stuff up until the Serbs finally decided to leave Kosovo – time was not an issue, there was no sense of urgency."[40] Secretary of Defense William Cohen and Chairman of the Joint Chiefs of Staff, General Hugh Shelton acknowledged the ad hoc and haphazard nature of the operation in their carefully worded statement to Congress after the war: "NATO adapted its military operations and target sets as the campaign proceeded, based upon an improved understanding of what the best approach should be. Thus, the types and locations of targets changed as the campaign proceeded."[41]

From the beginning, the campaign bore little resemblance to the ideal Air Force model, where parallel attacks against electricity, oil, transportation networks, leadership

[38] Lyon, *Operation Allied Force*, 3. Lyon was Commander, 22nd Fighter Squadron during ALLIED FORCE.
[39] Headquarters USAF, *Air War Over Serbia* (25 April 2000), 38. See also Beagle, *Effects-Based Targeting*, 76-77.
[40] Lyon, *Operation Allied Force*, 12.
[41] Cohen and Shelton, *Joint Statement*, 16. See also Clark, *Waging Modern War*, 276.

targets, or other centers of gravity inflict paralysis on an enemy system.[42] Although there were strikes against Serbian air defenses in the opening days of the campaign, many of the original fifty-one targets were symbolic, intended to demonstrate NATO's resolve without risking unnecessary casualties rather than achieve decisive effects. For example, the Air Force bombed the Lola Utva aircraft repair facility northeast of Belgrade on March 18 which, although it sat idle and nearly abandoned, was large and located far from civilian homes.[43] The first few weeks of the campaign were also not particularly intense, averaging only about fifty sorties a day compared to 1200 in DESERT STORM.[44] By the third day of the air war, General Short was forced to cancel the second wave of F-117's because he had already run out of politically approved targets.[45]

After several days of highly circumscribed bombing, the air campaign shifted to military and dual-use infrastructure throughout Serbia and by the eleventh day of the war, to the capital city of Belgrade. With Milosevic showing no signs of relenting, bombing intensity against military infrastructure increased in April in the hope that military leaders might convince Milosevic of the futility of resistance. When this strategy failed to produce, the campaign drifted to "crony targeting" in late April – destroying assets of the ruling elite to bring further pressure to bear on Milosevic.[46] By mid-April, the daily number of sorties had risen from 150 to between 450 and 500.[47]

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[42] Air Force Chief of Staff Michael E. Ryan later echoed the Air Force's concern: "The campaign did not begin the way America normally would apply air power – massively." Michael E. Ryan, "Air Power is Working in Kosovo," *The Washington Post* (4 June 1999), A35.
[43] William M. Arkin, "Smart Bombs, Dumb Targeting?" *The Bulletin of the Atomic Scientists* (May/June 2000), 46-48.
[44] Phillip S. Meilinger, "Gradual Escalation: NATO's Kosovo Air Campaign, Though Decried As a Strategy, May Be the Future of War," *Armed Forces Journal International* (October 1999), 18. See also Tilford, "Operation Allied Force and the Role of Air Power," 31.
[45] David Halberstam, *War in a Time of Peace: Bush, Clinton, and the Generals* (New York: Scribner, 2001), 444, 451.
[46] Arkin, "Smart Bombs, Dumb Targeting?," 50-51.
[47] Tilford, "Operation Allied Force and the Role of Air Power," 31.

By May, the air war shifted toward an expanded target set that included civilian infrastructure targets to undermine popular support for the Milosevic regime. Facing French opposition to kinetic strikes against the electric power system, the U.S. launched attacks on May 2 using special carbon filaments to short-circuit electrical transformers.[48] After these "clean strikes," the Serbs managed to restore electrical power within seven hours.[49] On 7 May, NATO struck with greater force against Belgrade and by the last week in May, the Air Force had persuaded Clark to reorient the air campaign almost exclusively toward its preferred "strategic" targets. By 22 May, NATO aircraft employed precision-guided munitions to "hard kill" the electrical system and on 24 May took the electrical grid out completely.[50]

Concluding that NATO "had gone about as far as possible with air strikes," Clark's strategy by mid-May was to "press the envelope" as political inhibitions gave way to the need to achieve decisive effects.[51] At a NATO meeting on 26 May, Clark showed Belgian and Czech ambassadors aerial photos of a building he planned to strike in Belgrade next to the their embassies, telling them to board up the windows with plywood.[52]

Needing to do something more, Clark requested that air planners submit 2000 targets in Yugoslavia for approval, "a large round number, large enough to get us past the daily struggle over the number of targets approved for that day." Clark's request was an example of the tail wagging the dog – striking more targets would require additional air

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[48] Stephen T. Hosmer, *Why Milosevic Decided to Settle When He Did* (Santa Monica, CA: RAND, 2001), 97-98.
[49] Rip and Hasik, *The Precision Revolution*, 395.
[50] Ignatieff, *Virtual War*, 107.
[51] Clark, *Waging Modern War*, 305.
[52] Priest, *The Mission*, 268.

forces, a step calculated to maintain the momentum of the faltering campaign.[53] The request, however, overtaxed the targeting system (even if only temporarily) and further encouraged the mechanical servicing of targets rather than the thoughtful application of air power. By the time the air war ended on 10 June with Milosevic's acquiescence, the air campaign had ballooned from fifty-one targets and 366 aircraft to almost 1000 targets and 900 aircraft (more aircraft, in fact, than the airspace over Serbia and Kosovo could accommodate).[54] By the beginning of June, Belgrade had only about six percent of its normal power supply and with no electricity to power pumps, the city was also without water. According to the U.N.'s Independent International Commission for Kosovo, what had started as a limited demonstration of resolve had ultimately destroyed two-thirds of the country's main industrial plants, seventy percent of the country's electrical production capacity and eighty percent of Yugoslav oil-refining capacity.[55]

Confident in air power's capability to coerce Milosevic, NATO entered the war over Kosovo anticipating a short and relatively limited air campaign. But exaggerated expectations for air power's precision and discrimination, the political complications of alliance warfare, and conflicting schemes for the application of air power collectively produced relatively ineffective attacks against targets that were politically easy but only tangentially related to the objectives of the campaign. Absent any effects-based strategy,

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[53] Clark, *Waging Modern War*, 250-251. Clark's original request was for 5000 targets but air planners persuaded him that there were not that many viable targets in all of Yugoslavia.
[54] Clark, *Waging Modern War*, 425. On the shortage of airspace, see Richard J. Newman, "The Bombs That Failed in Kosovo," *U.S. News and World Report* (20 Sep 1999).
[55] Priest, *The Mission*, 273. The air campaign destroyed five highway and railroad bridges, two oil refineries, some fifty-seven percent of petroleum reserves, fourteen dual-use industrial facilities, nine major electric power generating stations and a significant number of electric transmission towers. Hosmer, *Why Milosevic Decided to Settle*, 66-68.

airmen fell back upon a mechanical process of day-to-day management of target lists.[56] Milosevic's stubbornness and escalating Serb violence against Kosovars forced NATO to ratchet up the intensity of bombing in an effort to dial up more coercive effects. Under these pressures, the air war became a random walk that in the end fell upon success.

The Tactical Precision of ALLIED FORCE

Despite the imprecise and inexact nature of ALLIED FORCE at the operational and strategic levels, the air campaign was a show place for tactical and technological precision. In DESERT STORM only ten percent of combat aircraft could deliver precision weapons; by the time of ALLIED FORCE, more than ninety percent could.[57] Because of concerns about collateral damage and its political effects, one hundred percent of the weapons in the opening days of the campaign were precision-guided.[58] American ships and aircraft fired 329 cruise missiles (218 TLAMs and 111 CALCMs), most during the first month of the campaign.[59] Throughout the entire air war, approximately thirty-five percent of the weapons flung at Serbia were precision-guided – much higher than the eight percent during DESERT STORM.[60] The combination of the B-2 with the JDAM was, according to Lieutenant General Short, the "number one

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[56] General John Jumper, "Operation Allied Force: Strategy, Execution, Implications," address at Air Force Association Eaker Symposium, Washington, D.C., 16 August 1999.
[57] Department of Defense, *Kosovo/Operation Allied Force After-Action Report*, 88.
[58] William M. Arkin, "Operation Allied Force," in Andrew J. Bacevich and Eliot Cohen, eds., *War Over Kosovo: Politics and Strategy in a Global Age* (New York: Columbia University Press, 2002), 12.
[59] Rip and Hasik, *The Precision Revolution*, 382. The British were the only other NATO ally to use cruise missiles during ALLIED FORCE.
[60] All told, NATO expended some 28,236 bombs (the United States accounted for 21,120 of these or seventy-five percent of the total). Seventy percent of these were dropped in the last three weeks of the campaign. Of the 21,120 weapons employed by the United States, 6,728 or approximately thirty-five percent were precision-guided. Arkin, "Operation Allied Force," 21.

success story" of the air war.[61] The B-2 flew around one percent of the total number of combat sorties, but dropped one third of the precision munitions used during the campaign, including 656 JDAMs that the USAF claimed hit eighty-nine percent of their targets.[62] The bulk of the precision-guided weapons were nevertheless laser-guided bombs still constrained by the limitations of weather.

NATO's heavy reliance on precision weapons to reduce collateral damage resulted in a high expenditure rate that drove the cost of the campaign to over $4 billion.[63] The high expenditure rate also reduced stockpiles of precision weapons, especially of JDAMs and cruise missiles whose inventories were already low following Operation DESERT FOX in Iraq, forcing the Department of Defense to submit an emergency supplemental appropriations request to Congress during the course of the war.[64] The shortage of "smart" bombs also caused an increasing reliance on "dumb" bombs as the campaign progressed, especially as weather improved and degraded Serb defenses became less consequential in late May and June.[65]

As in DESERT STORM, dumb bombs played an essential role in ALLIED FORCE. One third of all bombs dropped were unguided Mk-82 500-lb bombs from B-1's and B-52's, most in the last two weeks of the war against fixed targets in Montenegro

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[61] Tirpak, "Short's View of the Air Campaign." "With all the political restraints on the air campaign, precision systems are what made the victory in Kosovo possible." Thomas Keaney quoted in Lawrence F. Kaplan, "Air Time," *The New Republic* (22 January 2001), 16.
[62] Lambeth, *The Transformation of American Air Power*, 194. Cordesman, *Lessons*, 180.
[63] Rip and Hasik, *The Precision Revolution*, 382. See also A. Owens, *Lifting the Fog of War* (New York: Farrar, Strauss, and Giraux, 2000), 144-145.
[64] Department of Defense, *Kosovo/Operation Allied Force After-Action Report*, 93-94.
[65] Ninety percent of weapons used through 15 April were "high end," although throughout the entire campaign, smart weapons accounted for only a third of all munitions expended. Earl H. Tilford, Jr. "Operation Allied Force and the Role of Air Power," *Parameters*, 29/4 (Winter 1999/2000), 31.

and Serbia and fielded forces in Kosovo.[66] Even unguided bombs, thanks to improved avionics, GPS for aircraft navigation, and computer release systems, were more accurate than ever before. The B-52 could now drop a string of fifty-four 500-pound bombs into a box no longer than 1000 feet as compared to greater than a mile during Vietnam.[67] In one attack on June 7, during a Kosovo Liberation Army (KLA) offensive, two B-52's and two B-1's dropped eighty-six Mk-82's and cluster bombs on a concentration of Yugoslav troops, initially thought to have killed as many as 600 enemy soldiers.[68] As the Department of Defense noted in its after action report to Congress, "Because pilots could now employ direct attack weapons at less risk, less costly legacy weapons were, in many cases, as effective (and sometimes more) as more costly preferred weapons against such targets as fielded forces, large military storage complexes, and airfields."[69]

Although the technical accuracy of bombing was better than in previous air campaigns, it was still less than the perfect. According to Pentagon accounting, of all weapons dropped – both guided and unguided – only fifty-eight percent hit their intended aim points. Of the 5,285 precision-guided weapons used during the campaign, seventy percent hit their aim points. Of the 421 fixed targets attacked during the NATO air campaign, the Air Force claimed only thirty-five percent destroyed, while about ten percent received no damage and the rest suffered varying degrees of damage.[70] These numerical statistics about weapons accuracy and degrees of damage, however, say little

[66] Whereas approximately ninety percent of the bombs dropped in the first month of the war were precision-guided, by late May guided weapons accounted for only ten to twenty percent of the total. Arkin, "Operation Allied Force," 21.
[67] Cordesman, *Lessons*, 180.
[68] Lambeth, *The Transformation of American Air Power*, 190, 196. Later indicated that NATO overestimated the number of Serb troops killed by American bombers. See especially Newman, "The Bombs That Failed in Kosovo."
[69] Department of Defense, *Kosovo/Operation Allied Force After-Action Report*, 90.

about the contribution of weapons to achieving desired outcomes. For a host of reasons, even unqualified technological and tactical proficiency did not directly guarantee operational and strategic effectiveness.

The Limits of Precision Air Power

The first constraint on the effectiveness of precision air power came from the complications of alliance warfare. ALLIED FORCE involved aircraft from fourteen different NATO countries, each with differing levels of capability and commitment. The majority of smart weapons were in U.S. stocks and NATO air forces, could not, for the most part, conduct all-weather and night operations.[71] Only U.S., British, Canadian, and French aircraft were equipped to drop laser-guided bombs and only U.S. aircraft could drop and launch GPS-based weapons. General Short readily acknowledged this capabilities disparity within his force: "I don't think there's any question that we've got an A team and a B team now."[72] Given concerns about collateral damage, there were many targets allies couldn't attack because of their lack of precision capabilities. For both political and technical reasons, strikes in the highest threat areas around Belgrade and north of the 44th parallel were limited to U.S. aircraft.[73] Consequently, U.S. aircraft flew over eighty percent of all strike sorties and fired over eighty percent of the precision-guided munitions.[74] Furthermore, American aircraft flew over ninety percent of aerial intelligence missions and American planners selected virtually every target attacked during ALLIED FORCE.

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[70] William Arkin, "Top Air Force Leaders to Get Briefed on Serbia Air War Report," *Defense Daily* (13 June 2000), 1.
[71] William C. Cohen, testimony to Congress, quoted in Cordesman, *Lessons*, 34. See also *ibid.*, 182-183.
[72] Tirpak, "Short's view of the Air Campaign."

Beyond the disparity in burden sharing, the capability differential between NATO allies created other frictions as well. NATO allies had to rely on the United States for key capabilities like intelligence, surveillance, and reconnaissance (ISR), aerial refueling, and airborne command and control, but many lacked compatible means for secure communications with U.S. aircraft. Because allied aircraft were not equipped to receive information through the Joint Tactical Information Distribution System (JTIDS), American pilots had to fall back on less-secure voice communications for the exchange of flight and target information.[75] Many European aircraft also lacked compatible identification-friend-or-foe (IFF) equipment to deconflict airspace and quickly distinguish friendly sorties. These technical problems of interoperability complicated the task of applying precision air power for both planner and operator alike.

The interactions of alliance warfare brought on other problems that plagued the operation. Targets required unanimous allied consent before NATO aircraft could strike. The French and Italian governments were largely opposed to the widening of the air war that the Americans and British favored.[76] The French in particular feared the impacts of unintended civilian casualties on domestic support for the war.[77] For example, the American and British proposal to bomb the Socialist Party Headquarters in Belgrade that estimated a worst case of 350 casualties from apartment buildings surrounding the complex drew stiff resistance from the French. The French, who had the second largest air component in the operation behind the Americans, also opposed intensifying strikes

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[73] Lyon, *Operation Allied Force*, 9.
[74] Cordesman, *Lessons*, 34
[75] Lambeth, *The Transformation of American Air Power*, 203.
[76] Clark, *Waging Modern War*, 236-237 and 449.
[77] See especially Dana Priest, "Bombing by Committee: France Balked at NATO Targets," *The Washington Post* (20 September 1999), A1.

against the electrical power network. Only in mid-May when failure appeared imminent did the need to intensify the air effort take precedence over Allied objections.[78]

The need for unanimous consensus among allies with differing conceptions for the war imposed constraints on the targeting process, limiting the efficient application of air power. The tortuous political approval process could not keep up with the 72-hour cycle of the air tasking order that matched aircraft to targets.[79] Planners nominated potential targets more for their political suitability and ease of obtaining approval than for their contribution to operational objectives. Targets were frequently changed or removed from the air tasking order as a result of this process, even as aircraft took off to attack them.[80] Work-arounds added even more complexity to the process. Under the pretext of imperfect interoperability, Americans developed two separate mechanisms for target selection and force application, one strictly for United States European Command and another for NATO as a whole.[81] This two-tier process gave the United States exclusive control over its most valuable precision-strike assets – B-2's, F-117's, and cruise missiles – and helped limit the interminable leak of operational information about upcoming strikes from less reliable allies.

The effectiveness of precision air power was also still contingent on the nature of the physical environment. Contrary to the claim of noted analyst Benjamin Lambeth, air operations in Kosovo demonstrated that air power has yet to conquer the weather as an

[78] Cordesman, *Lessons*, 35. General Short was particularly critical of the French stance against targeting infrastructure like the electrical system. See Short interview on PBS Frontline.
[79] See especially Dana Priest, "Target Selection Was Long Process," *The Washington Post* (20 September 1999).
[80] Priest, "The Battle Inside Headquarters," A1.
[81] Lambeth, *The Transformation of American Air Power*, 220-221.

operating limitation.[82] The majority of guided weapons were not GPS-capable JDAMs and spring weather in the Balkans proved problematic for line-of-sight weaponry like electro-optic and laser-guided bombs.[83] Cloud cover was greater than fifty percent for more than seventy percent of the time, affecting not only target areas, but also launch airfields and aerial refueling orbits.[84] During the first twenty-one days of the war, there were ten days where more than fifty percent of strike sorties were cancelled due to unfavorable weather.[85] Throughout the entire 78-day operation, there were only twenty-four days where weather did not hinder flight operations.[86]

Even GPS-guided munitions were less effective during periods of bad weather. The precision intelligence required both for target selection and for post-strike assessment demanded clear weather. Because there was no continuous weather satellite coverage for the region, aircraft were sometimes launched against targets only to find them obscured by cloud cover. The lack of flexibility in the 72-hour air tasking order process made redirecting and rescheduling flights with changing weather difficult. "I began to think," wrote General Clark, "that we had learned the wrong lessons from the forty-four day air campaign in the Gulf War, which [Clark wrongly believed] didn't have to face such weather related problems in the desert."[87] Milosevic was fully aware of the

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82 Lambeth contends "In having moved U.S. forces a generation beyond the era of electro-optical and laser guidance while, at the same time, having essentially conquered weather as an operating limitation, [GPS-guided weaponry] represents a new threshold crossed by American air power in its ability to achieve strategic effects in joint warfare." Lambeth, *The Transformation of American Air Power*, 162.
83 Rip and Hasik, *The Precision Revolution*, 405-406.
84 Cohen and Shelton, *Joint Statement*, 13.
85 Cordesman, *Lessons*, 21-23.
86 Department of Defense, *Kosovo/Operation Allied Force After-Action Report* (31 January 2000), 60.
87 Clark, *Waging Modern War*, 238. See the preceding chapter on the constraints of weather during DESERT STORM in 1991.

constraints that springtime weather imposed on NATO air power – improving weather in June probably helped convince him that even more intense bombing was on its way.[88]

NATO air power was also contingent on the nature of the terrain in the region. Unlike Kuwait and Iraq, Kosovo and Serbia are interspersed with mountains and thicker vegetation that make target detection and tracking a challenging problem. Moving targets, already difficult for GPS and standoff weapons requiring pre-programmed target coordinates, further complicated the problem.[89] The moving target indicator on the JSTARS did not have the capability to see over intervening ridges into valleys in Kosovo from distant orbits deemed safe from Serb air defenses.[90] Some of the most effective real-time targeting information came from the Army's Task Force HAWK that deployed to Albania. Their counter-battery radars, EH-60 helicopters, and RC-12 Guardrail aircraft proved useful in locating and targeting Serb positions in Kosovo. This capability, what one American general called "the eyes and the ears of the blacksmith so that the hammer of air power could be effective," was a windfall for air power operating against Serb forces in Kosovo, a positive and synergistic effect of joint operations previously unanticipated by air planners.[91]

But the most pervasive limitation haunting the air campaign was the political specter of unintended civilian casualties, that Clark identified as "a significant and frustrating problem."[92] Despite the technological and managerial care taken in delivering air weapons, the ratio of civilian casualties to tons of bombs dropped was the same for the 1999 air war over Serbia as it had been during the 1972 LINEBACKER campaign

[88] Hosmer, *Why Milosevic Decided to Settle*, xix-xx.
[89] See especially Evan C. Thomas, *The Future of All-Weather, Rapid Reaction Precision Targeting* (Maxwell AFB, AL: Air Command and Staff College, April 2000).
[90] Lambeth, *NATO's Air War for Kosovo*, 105-106.

over Vietnam.[93] By official Pentagon tally there were only twenty incidents of collateral damage, incidents which nevertheless had a major impact on international opinion.[94] According to Human Rights Watch, about five hundred civilians died in ninety separate incidents as a result of NATO bombing in Yugoslavia. This number, though far fewer than the 1,200 to 1,500 civilian deaths claimed by the Yugoslav government, was nonetheless a significant statistic for a campaign measured by its capacity to limit unintended casualties.[95]

Many of the unintended casualties came from the still inevitable stray weapon. Technical malfunctions and operator error were responsible for many of the "misses," including five missiles and bombs that missed Yugoslavia entirely and landed in Bulgaria — one in the capital Sofia.[96] Other factors, like recurring smoke and clouds that obscured targets, also played a part. Few U.S. crews had trained with live laser-guided bombs and were therefore unfamiliar with the complications of smoke and dust raised by live weapons.[97] On 5 April, two laser-guided bombs aimed at an artillery brigade headquarters in Aleksinac that failed to guide because of intervening smoke dove into a residential area, killing seventeen and wounding thirty.[98] Minimum altitude restrictions also accounted for many of the consequential misses. Although 15,000 feet may have been "the optimum altitude" for delivering precision weapons against fixed targets in well-identified positions, this altitude restriction was sub-optimum for unguided bombing

[91] Lt. General Theodore G. Stroup quoted in Lambeth, *The Transformation of American Air Power*, 213.
[92] Clark, *Waging Modern War*, 276.
[93] W.J. Fenrick, "Targeting and Proportionality During the NATO Bombing Campaign in Yugoslavia," *European Journal of International Law* 12/3 (2001), 493.
[94] Hammond, "Myths of the Air War Over Serbia," 81.
[95] "New Figures on Civilian Deaths in Kosovo War," online at http://www.hrw.org/press/2000/02/nato207.htm (accessed 7 September 2004).
[96] Tilford, "Operation Allied Force and the Role of Air Power," 38, n. 1. Clark, *Waging Modern War*, 214.
[97] Lambeth, *NATO's Air War for Kosovo*, 176-177.

and for visual identification of moving targets. The 15,000 foot floor also precluded descents below intervening cloud layers, negatively impacting targeting and weapons delivery.[99]

Although misses accounted for many of the nonlinear moments of the campaign, when tactical events produced major political effects, several were the result of bombs hitting precisely on their intended targets. On 12 April, an electro-optically guided AGM-130 fired from an American F-15E hit a rail bridge over the Jusna-Morava River near Leskovac in Kosovo. Unfortunately, the weapon struck just as a passenger train, unseen by both the pilot and weapon systems officer, crossed over the bridge, killing some fifty-five civilians.[100] After another daylight attack on the Varvarin Bridge in Belgrade on 30 May that killed nine and injured twenty-eight, NATO authorities instituted new rules limiting bridge attacks from 10:00 in the evening until 4:00 in the morning to avoid unintended civilian casualties.[101]

On 14 April, in another highly publicized incident, several F-16's dropped 500-pound bombs on two convoys at nearly the same time near the town of Djakovica in Kosovo. As one pilot related: "I have some chance from 15,000 feet up, with good daylight, or perhaps seeing unaided a large missile on a large truck, but smaller trucks, jeeps, and tanks, they all look similar."[102] What the pilots had thought to be Serb military

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[98] Rip and Hasik, *The Precision Revolution*, 400; Lambeth, *NATO's Air War for Kosovo*, 137.
[99] Phil Meilinger contends that 15,000 feet was not only a safer altitude, but also optimized the accuracy of precision weapons. See Phillip S. Meilinger, "Precision Aerospace Power, Discrimination, and the Use of Force," *Aerospace Power Journal* (Fall 2001), 12-20. Since GPS-weapons could be delivered accurately independent of altitude, B-2's delivered JDAMs from an altitude of 40,000 feet.
[100] Lambeth, *NATO's Air War for Kosovo*, 136, n. 87. In Clark's account (repeated in Rip and Hasik), the aircrew thought the train had stopped when their first missile hit the middle of the bridge. When they fired a second missile at the far end of the bridge, however, the train continued right into the missile's path. Clark, *Waging Modern War*, 254. See also Rip and Hasik, *The Precision Revolution*, 400.
[101] Hosmer, *Why Milosevic Decided to Settle*, 131, n. 15. Fenrick, "Targeting and Proportionality," 501. Clark, *Waging Modern War*, 334.
[102] Rip and Hasik, *The Precision Revolution*, 400.

vehicles were in fact civilian vehicles and as many as seventy-three ethnic Albanians were killed.[103] Pilots thereafter had to get clearance for vehicle attacks from the Combined Air Operations Center with General Short often making the final decision. Although the incidents led to a tightening of the target approval process, they also resulted in a slight loosening of Short's 15,000-foot altitude restriction. Thereafter, forward air control aircraft and even some bomb-droppers were allowed to go below this altitude for better identification of intended targets.[104]

The most politicized direct hit came on 7 May when a B-2 dropped JDAMs that hit the Chinese Embassy in Belgrade with unblemished accuracy, killing four and wounding another twenty-six.[105] Like the Al Firdos incident during DESERT STORM, the Chinese Embassy bombing was not the result of imprecise bombing, but of imperfect knowledge. The intended target was a logistical center for the Serb government, but analysts without recent experience on the ground using outdated maps forwarded the wrong target coordinates. The bombing created a diplomatic storm between Beijing and Washington – the Chinese found it hard to believe that the Americans, with all of their high-tech equipment, could unintentionally have made such an error. The immediate operational effect was a two-week halt to bombing targets within a five-mile radius of Belgrade's center. Two weeks off, however, did little to preclude future incidents. When NATO went back downtown on May 20, misplaced bombs damaged the residences of the Swiss, Swedish, Norwegian, and Spanish ambassadors.[106]

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[103] Clark, *Waging Modern War*, 254-255.
[104] Fenrick, "Targeting and Proportionality," 501.
[105] Lambeth, *NATO's Air War for Kosovo*, 144-147. Rip and Hasik, *The Precision Revolution*, 398-399.
[106] Barry R. Posen, "The War for Kosovo: Serbia's Political-Military Strategy," *International Security* 24/4 (Spring 2000), 72.

The Chinese Embassy attack was, according to Clark, "a huge gift to the Serb propaganda effort. ...The weight of public opinion was doing to us what the Serb air defense system had failed to do: limit our strikes."[107] Throughout the campaign, Serbs maintained a sustained media effort using domestic television broadcasts, the internet, and their access to the international press corps that highlighted and distorted civilian casualties.[108] E-mails, faxes, and phone calls carried immediate information about the strikes, both positive and negative, out of Yugoslavia throughout the war.[109] As NATO political authorities rightly feared, instantaneous feedback made the conduct of the war more transparent, multiplying the negative political effects of aerial violence on their general publics. Precision weapons, in one way, contributed to this phenomenon since now reporters could stand in relative safety right in the middle of the action.[110] Tactical errors that might previously have been overlooked became highly publicized and politicized mistakes with the potential for dividing NATO and the international community while encouraging Milosevic and Serbia to stay in the game.[111]

But civilian casualties probably also made a positive contribution to successful outcomes as well. Granted NATO was not wiping out cities to demonstrate their resolve, but attacks in Belgrade with accompanying collateral damage communicated that the alliance was willing to take political risks in intensifying the air war. Civilian casualties convinced the Serbian leadership, who thought that NATO was deliberately targeting civilian as well as military targets, that NATO had the freedom to destroy the entire regime at will if need be. NATO thus benefited from the distorted perception of both the

[107] Clark, *Waging Modern War*, 444.
[108] Hosmer, *Why Milosevic Decided to Settle*, 30-32.
[109] Ignatieff, *Virtual War*, 139.
[110] Ignatieff, *Virtual War*, 192-196.

intent as well as the capabilities of the air campaign in persuading Milosevic to accept the terms of the political settlement.[112] Precision air power, in an important yet unintended way, contributed to these perceptions. "NATO missiles have largely been so precise that many Serbs no longer believe that NATO ever bombs in error, even if the damage is to the Chinese Embassy of a hospital."[113] Both friend and foe alike overestimated the capacities of precision air power with mixed results for the outcome of the conflict.

The precision air campaign was less of a shock to the Serbs than it had been to Iraqis in 1991.[114] The active and passive measures the Serbs took to reduce the effectiveness of air power made the campaign for Clark "a race of our destruction against Milosevic's improvisation, repair, work-arounds, and reconstruction."[115] The Serbs often had prior notice of NATO strikes and most fixed military targets were empty when bombs hit – the "empty building syndrome." One of these buildings was Milosevic's official residence, which had been empty for some time before it was destroyed with cruise missiles on 22 April.[116] Although the physical effects of on empty buildings were impressive, the bombs did little damage to the political will of the country.[117]

The Serbs were particularly adept at the use of camouflage, deception, and concealment.[118] Water receptacles dressed up like vehicles would heat up during the day, producing infrared signatures similar to real vehicles. Even relatively crude decoys – like tanks reportedly built out of milk carton material – created problems for NATO

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[111] Posen, "The War for Kosovo," 70.
[112] Hosmer, *Why Milosevic Decided to Settle*, 131.
[113] Steven Erlanger, "Belgrade's People Still Defiant, but Deeply Weary," *New York Times* (24 May 1999), A1, A14. Quoted in Hosmer, *Why Milosevic Decided to Settle*, 55.
[114] Rip and Hasik, *The Precision Revolution*, 212 and 401-402.
[115] Clark, *Waging Modern War*, 252.
[116] Rip and Hasik, *The Precision Revolution*, 394.
[117] Rip and Hasik, *The Precision Revolution*, 421.
[118] Department of Defense, *Kosovo/Operation Allied Force After-Action Report*, 61-63.

reconnaissance and intelligence assets.[119] One measure of the success of Serbian decoys was that NATO pilots by the end of the campaign claimed the destruction of more MiG fighters on the ground than the Yugoslav air force actually had.[120] Most movement of ground forces occurred only at night or under the cover of bad weather, hugging not only the terrain but also the local population that NATO went to such lengths to protect.[121] The Serbs, taking from eight years of Iraqi experience against precision airstrikes, also used smoke generators to deflect laser-guided bombs.

The coevolutionary nature of the war despite the asymmetry of opposing forces was perhaps most evident in NATO's battle to neutralize the Serbian integrated air defense network. By taking simple measures like turning off, dispersing, and concealing radars – tactics similarly learned from the Iraqi experience under the no-fly zones – the Serbs were able to preserve a majority of their air defense system.[122] The NATO air campaign focused on suppression, rather than destruction, of Serbian air defenses. But when the air campaign ran longer than anticipated, the Serbian air defenses reemerged as a lingering threat.[123] Pilots complained that the emphasis on suppression rather than destruction of air defenses put aircrews at greater risk over time.[124] Political considerations also made the task of neutralizing air defenses more difficult since airmen

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[119] Cordesman, *Lessons*, 188-189.
[120] Rip and Hasik, *The Precision Revolution*, 391.
[121] Posen, "The War for Kosovo," 56-57.
[122] Department of Defense, *Kosovo/Operation Allied Force After-Action Report*, 64-66. See also Philip Shenon, "The Iraqi Connection: Serbs Seek Iraqi Help for Defense, Britain Says," *New York Times* (1 April 1999), A16.
[123] Lambeth, *NATO's Air War for Kosovo*, 102-116.
[124] Lyon, *Operation Allied Force*, 17.

could not get the necessary approval to attack early warning radars in Montenegro that cued Serbian defenders to the approach of NATO aircraft.[125]

Although only two NATO aircraft were shot down (a Dutch F-16 and an American F-117), air defenders fired 845 surface-to-air missiles throughout the campaign, most of which were SA-3's and SA-6's.[126] The 15,000-foot altitude restriction protected aircraft and crews from man-portable weapons but not from more robust SA-3 and SA-6 missiles. The persistence of threatening air defenses throughout the war obliged more assets to their continued suppression rather than to strike sorties and required the repositioning of high value assets like the U-2 and J-STARS to distant orbits out of harm's way. Serbian air defenses remained dangerous enough to keep the Army's Apache helicopters out of action throughout the war. Enemy adaptation and an emphasis on the effect of suppression rather than destruction contributed to the inefficiency of the air campaign.

The Serbs were also successful at safeguarding their forces in the field from NATO air power. NATO bombing did not greatly reduce the effective numbers of the Yugoslav Army, especially the Third Army and the Ministry of Internal Affairs Police Forces in Kosovo that were mobile and therefore difficult to locate, positively identify, and destroy.[127] The U.S. Air Force, in part due to the nature of GPS weaponry and the neglect of real-time targeting capabilities since the Gulf War, entered ALLIED FORCE unprepared for the counter-land portion of the precision fight. The Air Force introduced

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[125] Clark complained that NATO authorities were treating the Yugoslav province of Montenegro like an allied country. Clark, *Waging Modern War*, 241.

[126] Throughout the campaign, the Serbs launched 188 SA-3's, 477 SA-6's, 124 man-portable missiles, and 56 unidentified types. Arkin, "Operation Allied Force," 14. The Serbs also downed twenty-five unmanned aerial vehicles. *Ibid.*, 22. According to Lambeth, the stealthy F-117 was downed by "a lucky combination of low-technology tactics, rapid learning and astute improvisation" on the part of the Serbs. Lambeth, *NATO's Air War for Kosovo*, 116-120.

its one dedicated ground attack asset, the A-10, only gradually, allowing the Yugoslav Army to effectively adapt to its strengths and weaknesses.[128] Destruction of Serbian fielded forces was all the more difficult without a competent friendly ground force to identify targets and guide in strikes.

Although air power did not destroy the Yugoslav Army, it did scatter their forces and prevent them from operating in the open. Contrary to General Clark's claim, however, simply scattering Serb forces did little to hinder the ethnic cleansing campaign and made them even less vulnerable to air power.[129] The American counter-reaction to Serb dispersal tactics was "flex targeting" where aircraft took off without specific targets and then were either directed by forward air controllers or searched independently for pop-up ground targets. Throughout the campaign, NATO aircraft bombed more than 3400 flex targets.[130] This method, however, added to the inefficiency of the air campaign. Aircrews that did find targets needed commanders' approval before they could strike; the time required to obtain approval often either exceeded the available loiter time of the strike aircraft or gave mobile ground targets time to escape.[131] Striking mobile targets with standoff and GPS weapons was still exceedingly difficult, as was the problem of accurately assessing the damage done.[132] After the war, the Department of Defense assessment team could confirm only sixty percent of the hits claimed against mobile targets.[133]

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[127] Hosmer, *Why Milosevic Decided to Settle*, 77-90.
[128] Rip and Hasik, *The Precision Revolution*, 393.
[129] Clark, *Waging Modern War*, 198.
[130] Department of Defense, *Kosovo/Operation Allied Force After-Action Report*, 34
[131] On the Combined Air Operations Center's "force-level execution (FLEX) targeting cell," see especially Haave and Haun, eds., *A-10's Over Kosovo*, 141-142. On the inefficiencies of the target approval process, see *ibid.*, 146-153.
[132] Cordesman, *Lessons*, 180 and 198.
[133] Department of Defense, *Kosovo/Operation Allied Force After-Action Report*, 84-85.

Anticipating and then assessing the effectiveness of air power was a pressing problem throughout the air campaign. "The difficulty was that we could not guarantee any specific level of damage from the air," Clark complained, "much less predict it."[134] NATO's strategic focus was on the operations of Serbian forces in Kosovo, but there was no easy way to measure air power's effectiveness at influencing their unwanted behaviors. Uncertainty and the lack of information, an inevitable constant in a war waged under adverse operational and environmental conditions, plagued the assessment effort. Estimates of the effectiveness of air power against the Yugoslav army varied widely throughout the war.[135] Analysts were still unable to confirm the destruction of a single military vehicle by the end of the third week of the war. With the effects of the air campaign undetermined, military commanders resorted to asserting strategic effectiveness based on self-selected information, including questionable pilot reports that pointed to tactical success.

Asserting effectiveness, however, was not the same as attaining effectiveness.[136] Despite NATO claims, Serb forces were still able to carry out their ethnic cleansing campaign in Kosovo. After six weeks of bombing, there were more Serb forces in Kosovo than when ALLIED FORCE began.[137] After the war, the Commander in Chief of the Yugoslav Army claimed that only 524 soldiers had been killed, in sharp contrast to NATO estimates in the thousands.[138] Operation Horseshoe – the "forced migration" of ethnic Albanians from Kosovo initiated in March – intensified with NATO bombing. Between March and June 1999, Serbs expelled no fewer than 863,000 Kosovar Albanians

[134] Clark, *Waging Modern War*, 299.
[135] See especially "The Kosovo Cover-up," *Newsweek* (15 May 2000), 19-24.
[136] Cordesman, *Lessons*, 145.
[137] Lambeth, *NATO's Air War for Kosovo*, 120-121.

while as many as 590,000 others were displaced within Kosovo – a total of more than ninety percent of the Albanian population in Kosovo.[139] In the end, the extent of the ethnic cleansing campaign may have only been limited by the fact that the Serbs were running out of Albanians to move and their desire to keep some around to protect against unrestrained NATO bombing.

The ease of striking and assessing things, not the dictates of effective strategy, drove NATO target selection.[140] Heavy military equipment was easier to hit and assess than light forces and paramilitary units terrorizing Kosovar Albanians. Airmen schooled in effects-based operations chafed at the fixation on more easily quantified measures of destruction that diverted attention from true indicators of air power effectiveness. General Joseph Ralston, then Vice Chairman of the Joint Chiefs of Staff noted: "The tank, which was an irrelevant item in the context of ethnic cleansing, became the symbol for Serb ground forces... All of a sudden, this became the measure of merit that had nothing to do with reality."[141] General John Jumper, the commander of U.S. Air Forces in Europe, put it most succinctly: "Now we're hitting things, and he's killing people."[142]

Counting vehicles destroyed was not only irrelevant, but it also turned out to be no easier than it had been thirty years earlier in Vietnam. NATO initially claimed that it had disabled 150 of Serbia's 400 tanks but later scaled that claim back to 110. Post-war

[138] Lambeth, *NATO's Air War for Kosovo*, 129-130.
[139] Hosmer, *Why Milosevic Decided to Settle*, 25. See also Merrill S. McPeak and Robert Pape, "Hit or Miss: What Precision Weapons Do, Precisely," *Foreign Affairs* (September/October 2004), 163. Pape claims that Serbian forces killed more than 2,400 Albanian civilians in Kosovo and expelled nearly 900,000.
[140] "[NATO] tended to bomb by category and judge its success largely by perceived damage to physical facilities, rather than any clear insights into enemy perceptions and behavior." Cordesman, *Lessons*, 101.
[141] General Joseph Ralston quoted in Priest, "The Battle Inside Headquarters," A1. See also Lambeth, *NATO's Air War for Kosovo*, 134; and Arkin, "Operation Allied Force," 27.
[142] Clark, *Waging Modern War*, 233.

inspectors in Kosovo found few ruined vehicles to confirm these claims.[143] As in COMMANDO HUNT, quantified measures of air power's tactical effects blinded analysts to more obvious strategic realities. Airmen in both cases were never sure how many vehicles were destroyed, but did know that air power had stopped neither the flow of supplies from North Vietnam nor the progress of ethnic cleansing in Kosovo.[144] Increased technological precision did little to clarify the political impacts of bombing. The difficulties of alliance warfare, the vagaries of the physical environment, concern for the political impact of civilian casualties, enemy reaction and adaptation, and inadequate information about the effects of the air campaign all converged to limit the effectiveness of precision air power in achieving desired outcomes.

The Demands of Precision Air Power

ALLIED FORCE demonstrated the paradox that increasingly capable air weapons can create conditions that reduce their ultimate effectiveness. Expectations of "antiseptic" warfare set a high bar for the campaign. Although airmen classified thirty percent of precision-guided weapons in ALLIED FORCE as "misses," these misses were calculated using an incredibly high standard of accuracy. A weapon landing outside the thirty-foot circular error probable expected of a JDAM, for example, contrary to public perception formed from highly publicized incidents of collateral damage, would only rarely cause civilian casualties.[145] Despite (or because of) the increasing adeptness of airmen at minimizing mistakes, the exacting standards of a quickly critical media magnified the effects of these mistakes, making incidents like the bombing of the Chinese

[143] Lambeth, *The Transformation of American Air Power*, 197. Arkin, "Operation Allied Force," 25.
[144] Tilford, "Operation Allied Force and the Role of Air Power," 32-34.

embassy all the more politically painful.[146] Because airmen can potentially wield air power discriminately, precisely, and bloodlessly, they are expected to do so – even sometimes at the expense of strategic effectiveness.[147]

In the end, air power did indeed work. Although air power did not immediately stop the ethnic terror against Kosovar Albanians, it did ultimately force Milosevic to withdrawal forces from Kosovo and comply with NATO demands along the line of the Rambouillet Accords. The operation also demonstrated the potential for concerted action by NATO members and the ultimate resilience of the alliance.[148] But there were lasting strategic consequences to the victory and the accompanying perception that American air power had done it alone with less positive connotations. One of these consequences was that future enemies looked to alternative methods of warfare, like insurgency and terrorism, not only less susceptible to air power, but also potentially more deadly to the civilian populations precision air power has aimed to protect. A second strategic consequence has been the greater willingness on the part of American administrations to apply military force to what were previously considered intractable problems.[149] As General Jumper observed, "Our problem with all of this is we make it look too easy. ...It makes it look as if airpower is indeed risk free and too easy a choice to make."[150] In these ways, precision air power has played a role not in simplifying or linearizing warfare, but in making it even more complex and potentially more deadly.

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[145] Arkin, "Smart Bombs, Dumb Targeting?" 49.
[146] Lambeth, *NATO's Air War for Kosovo*, 139-140. See also Major General Charles Wald, Department of Defense Briefing, 2 June 1999.
[147] Cordesman, *Lessons*, 52-59.
[148] Byman, "Kosovo and the Great Air Power Debate."
[149] See especially Andrew J. Bacevich, *The New American Militarism: How Americans are Seduced by War* (New York: Oxford University Press, 2005), 20-22.

Despite outward appearances, the case of Kosovo does not validate John Keegan's claim that war could be won by air power alone.[151] Analysts arriving at this conclusion commit the fallacy of *post hoc, ergo propter hoc.* Because Milosevic capitulated after seventy-eight days of air bombardment does not mean that air power was alone sufficient. Success was contingent on many contributing factors beyond air power including Russia's lack of support for Serbia, the ground offensive by the Kosovo Liberation Army, and the growing threat of a NATO ground invasion. Serbia was a small power with limited military capability, surrounded on all sides by countries friendly to NATO. That air power took the time it did under these circumstances is probably more notable than its single-handed success.

Perhaps a better lesson to draw from the experience concerns the synergies that come from the combination of coercive forces. Air power was most effective in Kosovo when two conditions occurred, one strategic and one tactical: when the Russians pressured Milosevic and when Serb forces massed to meet a KLA offensive, exposing themselves to B-52 strikes.[152] An enemy facing an imminent invasion will react differently to air power.[153] Insisting that air power be independently decisive sacrifices the potentially synergistic effects of combining land and air power. Even General Short recognized the limits of air power applied alone: "[T]his conflict was unlike others in that we did not have a ground element to fix the enemy, to make him predictable, and to give us information as to where the enemy might be."[154]

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[150] General John P. Jumper quoted in James Kitfield, "Another Look at the Air War That Was," *Air Force Magazine* 82/10 (October 1999).
[151] John Keegan, *London Daily Telegraph*, 6 June 1999.
[152] Cordesman, *Lessons*, 169-176.
[153] See especially Thomas A. Keaney, "The Linkage of Air and Ground Power in the Future of Conflict," *International Security* 22/2 (Fall 1997), 147-150.
[154] Quoted in Lambeth, *NATO's Air War for Kosovo*, 242.

Successful outcomes are usually the result of the interaction of causes, not just the effect of a single cause. Opposing systems suffer the coercive effects of air power only in the context of other stresses and supports. The combination of factors weighing on an opponent can be either additive or synergistic.[155] While accumulating damage may sometimes wear down the material strength or will of an opponent, there will sometimes be combinations of inputs – like the combination of the air war with the threat of a ground invasion – that tip the scales toward success.

While air power can be very accurate in a technological sense, the air war over Kosovo confirmed that air power, as an instrument of social and political control, is necessarily much less efficient and precise. "It is the politics of the moment that will dictate what we can do," reflected General Jumper after the experience. "If the limits of that consensus mean gradualism, then we're going to have to find a way to deal with a phased air campaign. Efficiency may be second."[156] The political restrictions that bound the Kosovo air campaign were not a historical exception, but rather the rule. Although shifting objectives and political restraints on the air campaign irked operationally-focused airmen like General Short who complained about "air power not being used as well as it could be and the way you have been taught to use it," it was exactly these restrictions that were responsible for air power's ultimate success.[157] Without consensual decision-making and measures to reduce collateral damage and loss of civilian life, the political cohesion of the NATO alliance might well have given way long before air power had its intended effect on the will of Milosevic and the Serbian people.

[155] See especially Daniel L. Byman, "Kosovo and the Great Air Power Debate," *International Security* 24/4 (Spring 2000), 5-39.

Airmen will rarely get the war they want to fight. The reason for this is simple: no matter how precise the technology, war remains a political act wrapped in chance and uncertainty. The precision with which weapons hit the target will rarely equate with the effectiveness of bombing in achieving strategic and political objectives. Successful outcomes demand that airmen fight war as a whole, being proficient not only in tactical capabilities and operational methods, but also well-versed in their likely higher order strategic and political effects.

[156] Quoted in Lambeth, *The Transformation of American Air Power*, 229. See also Elaine M. Grossman, "Ralston Sees Potential for More Wars of Gradual Escalation," *Inside the Pentagon* 15/37 (16 Sep 1999), 1.
[157] Tirpak, "Short's View of the Air Campaign."

Conclusion

"[T]o some degree all clocks are clouds; ...only clouds exist, though clouds of very different degrees of cloudiness."

Karl Popper[1]

The preceding chapters on nonlinearity and its impacts on American air power are admittedly less than exhaustive. They do not draw exclusively from documentary evidence, are weighted toward the case of the United States Air Force, and do not give a complete chronological account of the history of air power. Such a comprehensive account, however, was not the intent of this analysis. By putting precision air power and its enabling technologies in their military, political, and social context, this study has shown that success in air warfare depends as much on our intellectual approaches as on the airplanes we fly or the bombs we drop.[2] American airmen have often approached the phenomenon of war like engineers designing a bridge over an unresisting river. War, however, is a competitive social process between adapting opponents, each seeking to thwart the other's intentions. Although airmen have successfully engineered the weapons of war, they should not expect to so closely engineer the course and outcomes of war. Advanced technologies may alter the ways in which wars are fought, but they will not change the fact that wars are nonlinear affairs fought among human beings for subjective political ends.

Nonlinearity has had a profound influence on the evolution of American precision air power, at once inspiring greater accuracy for greater control over its effects, while at

[1] Karl R. Popper, "Of Clouds and Clocks: An Approach to the Problem of Rationality and the Freedom of Man," in Popper, *Objective Knowledge: An Evolutionary Approach* (Oxford: Clarendon Press, 1972), 213.

the same time frustrating these very aspirations. Greater technical precision fits well with American cultural traits. American partiality for precision air power reflects a reasonable preference for technological solutions to social problems and a commonsense desire for war waged from a distance without unnecessary bloodshed.[3] This preference is the product of larger historical, cultural, and geographical forces, but also of the agency of key individuals like General HAP Arnold, who actively promoted science and technology in the United States Army Air Forces. As Arnold himself noted, the faith and confidence in air power is "the logical outgrowth of a national philosophy which believes firmly in the expenditure of machines rather than men. ...Machines are cheap in America; men are not."[4]

Air power has also appealed to Americans because it is inherently nonlinear. Small inputs (single bombs) can potentially have major military and political consequences. Precisely delivered air power – given its speed, range, lethality, and ubiquity – is a useful military tool for imposing inefficiencies on an opponent. Theorists of the 1920's and 1930's who advocated high-altitude strategic bombing sought to impose the nonlinearities of air power on opponents, as have later airmen like John Warden and David Deptula in their theories of parallel warfare and effects-based operations. Precision air power is analogous to the butterfly in the metaphor of chaos with the recognized potential for higher order effects. The challenge, however, is in correctly anticipating and managing the strategic and political storms that air power can generate.

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[2] Changing the predominant intellectual paradigm is an essential element of the ongoing transformation of the American military. See especially *Elements of Defense Transformation* (Washington, D.C.: Office of the Secretary of Defense, October 2004).
[3] Eliot Cohen, "The Mystique of Air Power," *Foreign Affairs* 73/1 (January/February 1994), 120.

The general trajectory of American air power has been toward greater precision and discrimination. Progress toward this objective, however, has not been steady and linear, but rather has followed a path best described by the term "punctuated equilibrium." Within this larger progression, there has been a "strange attractor" or repeating trend of decreasing discrimination within individual wars, a trend Paul Fussell has called "the inexorable progress from light to heavy duty." As campaigns intended to end quickly with "shock and awe" settle into wars of attrition, the accumulating abundance of air resources, growing frustrations, and acclimation to the increasing intensity of bombing lead to "a coarsening of technique," often overshadowing concerns for discrimination.[5] In Korea, for example, when precision attacks on industry and transportation failed to "strangle" or "saturate," Americans resorted to less precise but potentially more coercive strategies like dam busting and city bombing to pressure their Communist opponent. This attractor seems to hold even in the most politically sensitive campaigns, as in the air war over Kosovo, where the urgency of winning eventually superseded political requirements for perfect discrimination. Mass bombing still holds a place in the age of precision.[6]

Airmen have typically equated the accuracy of air power with its efficiency. In fact, the words are used interchangeably in the official history of American air operations

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[4] From an Army Air Forces study commissioned by General Arnold, "Comparison of Air and Ground Warfare, 1941-1944," August 1944, 69-70. AFHRA file no. 105-4.

[5] Paul Fussell, *Wartime: Understanding and Behavior in the Second World War* (New York: Oxford University Press, 1989), 7-8. Commenting on the war in Korea, historian Frank Futrell ascribed this tendency toward decreasing bombing accuracy to "the general nature of static war." Robert F. Futrell, *The United States Air Force in Korea* (Washington, D.C.: Office of Air Force History, 1996), 645.

[6] This strange attractor of decreasing discrimination also reflects a process noted by Clausewitz where interacting opponents led by "the impulse to destroy the enemy" tend to drive warfare to its theoretical extremes. Carl von Clausewitz, *On War*, Michael Howard and Peter Paret, eds. and trans. (Princeton: Princeton University Press, 1976), 75-77.

in the Second World War.[7] There is a difference, however, between the efficient use of means and the effectiveness of their contribution toward ends. Although precision air power is efficient, the tactical efficiency of precision is not the same as strategic and political effectiveness.[8] As Russell Ackoff has written, "Effectiveness is *evaluated* efficiency. Efficiency is concerned with doing things right; effectiveness is concerned with doing the right thing."[9] Doing the right thing in war implies tactical actions whose effects are in full accord with desired political outcomes. As NATO spokesman during ALLIED FORCE Jamie Shea put it, "It is not enough to win. One must win in the right way."[10]

Because the higher order consequences of war emerge from a confluence of factors, there can be no clean separation between causes and effects.[11] Despite improvements in technology and technique, air targeting and battle damage assessment are still inexact arts.[12] The uncertainties that arise from imperfect intelligence and enemy actions at the tactical level accumulate at the operational, strategic, and political levels of war, making likely effects all the harder to predict.[13] For these reasons, translating the

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[7] Wesley Frank Craven, and James Lea Cate, eds., *The Army Air Forces in World War II* (Washington, D.C.: Office of Air Force History, 1983), v. 2, 343-346.
[8] Stephen T. Ganyard, "Strategic Air Power Didn't Work," *U.S. Naval Institute Proceedings* (August 1995), 34-35. Donald Mrozek writes: "Efficiency means merely the skillful execution of a predetermined routine; effectiveness suggests that the routine had a useful purpose and that executing it achieved the predetermined goal." Donald J. Mrozek, *Air Power and the Ground War in Vietnam: Ideas and Actions* (Maxwell AFB, AL: Air University Press, 1988), 2.
[9] Russell Ackoff, "OR: After the Post Mortem," *Systems Dynamics Review* 17/4 (June 2001), 345.
[10] Quoted in R. A. Renner, "America's Asymmetric Advantage: The Utility of Airpower in the New Strategic Environment," *Defence Studies* 4/1 (Spring 2004), 91.
[11] "[I]n war, the advantages and disadvantages of a single action could only be determined by the final balance." Clausewitz, *On War*, 182.
[12] See for example Robert Wall, "Aimpoint Adjustment: Pentagon Identifies Need For Better Targeting, Battle Damage Assessment, and Reliability," *Aviation Week and Space Technology* (18 October 2004), 43.
[13] "Thus, to measure effectiveness, as opposed to effects, becomes a problem of such magnitude as to be impractical, requiring as it does the evaluation of an almost limitless number of decisions leading up to the attack order." David MacIsaac, *Strategic Bombing in World War II: The Story of the United States Strategic Bombing Survey* (New York: Garland Publishing, Inc., 1976), 161-163.

mechanical efficiency of precision into desired political outcomes has been exceedingly difficult.

Although ultimate political outcomes are what matters most in war, airmen have historically focused on the quantifiable, first order effects of air power. American airmen, enthralled with the destructive means of air warfare, have given inadequate consideration to the qualitative nature of desired ends.[14] In the spring of 1944, airmen counted bridges, rail lines, and rail cars destroyed without thoroughly understanding the impacts of this destruction on the defensive capabilities of the *Wehrmacht*. In Vietnam, the Air Force tallied trucks, but this tally said little about the effectiveness of insurgent forces in the south. In Kosovo, precision bombs destroyed buildings, but the destruction of empty buildings had questionable impact on the Yugoslav Army's extermination campaign or the political will of Serb leaders. The perceived efficiency and cost-effectiveness of precision air power, much like the automated answering system that shifts the burden from receptionist to caller, often only transferred the unavoidable costs of war.[15] Transportation attacks before D-Day efficiently destroyed the very roads and rails required by the land forces in their offensive across France. Discriminate attacks on critical infrastructure in Iraq and Kosovo, although intended to avert civilian suffering, shifted much of the burden of the air war onto the backs of the civilian population.

[14] Or as Mrozek writes, airmen have tended to confuse the instruments of air power with the principles of air power. Mrozek, *Air Power and the Ground War in Vietnam*, 16. On this same theme, see also Carl Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the United States Air Force* (New Brunswick, NJ: Transaction Publishers, 1994).

[15] See Nicols Fox, "We Could Do Worse: The Case Against Efficiency," *The Washington Post* (15 February 2004), B1.

Because war is nonlinear and usually anything but efficient, it is effectiveness and not efficiency that should be first in the minds of air commanders.[16] Although the majority of airmen have considered strategic bombing the most efficient use of air power, military and political necessities have frequently imposed other obligations. As Hoyt Vandenburg grudgingly admitted in the midst of the Korean conflict in 1951, "Air power... should go to the heart of the industrial centers to become reasonably efficient. ...In my opinion, the proper way to use air power is initially to stop the flow of supplies and ammunition, guns, equipment of all types, at its source. The next most efficient way is to knock it out along the road before it reaches the front line. The least efficient way is after it gets dug in at the front line. Nevertheless, there are requirements constantly where the utilization of air power in close support is necessary."[17] Airmen have argued that hitting strategic targets with bombers is air power's most useful function, but the historical record shows that tactical aircraft providing close air support and aerial interdiction have also done much of the yeoman's work. Tactical aircraft have not only been more precise, but arguably contributed more to the achievement of desired outcomes in World War II, Korea, and Vietnam. With the development of effective standoff guided weaponry since Vietnam, the type of delivery platform and the categories

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[16] See especially *Gulf War Air Power Survey*, Vol. 1, Part II: *Command and Control* (Washington, D.C.: Government Printing Office, 1993), 333. As Lt. Gen. Walter Buchanan, senior commander of U.S. aircraft in the Persian Gulf region, quipped when questioned about the inefficient use of cargo planes to transfer ground power around Iraq: "He (his boss, Gen. John Jumper) is not worried about efficiencies, and so I'm not either." Quoted in Bradley Graham, "Dangers on the Ground in Iraq Lead to Increased Use of Airlifts," *The Washington Post* (12 December 2004), A28.
[17] Hoyt S. Vandenburg quoted in Robert F. Futrell, *Ideas, Concepts, Doctrine: A History of Basic Thinking in the United States Air Force, Volume 1: 1907-1964* (Maxwell AFB, AL: Air University Press, 1971), 301.

of missions they perform have taken second seat to the capabilities of individual weapons.[18]

The advance of weapons and information technologies is not only erasing the distinction between tactical and strategic aircraft, but is also shrinking the space between the tactical and political levels of war.[19] Although war has always been nonlinear, in the age of smart bombs and instantaneous communication the manifestations of this nonlinearity come quicker and often carry greater effect. By compressing the time cycles of action and reaction, parallel warfare contributes to this trend.[20] Technological failure or human error may occur less frequently, but these anomalies now have the potential to spin quickly into major strategic and political events. There was little concern over the tons of bombs that missed in Germany and Japan; a single bomb that misses in Iraq today, on the other hand, is a news item with strategic implications. This is not to say that the political consequences of unintended imprecision are always bad, as the case of the capitulation of Milosevic may show. Airmen and their political masters, however, must carefully consider to which side these consequences might fall before letting slip the guided weapons of air warfare.

Faced with the problem of predetermining the effects of air warfare, airmen have turned to the scientific method in strategy and analysis. At its heart, the scientific method

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[18] As Tom Ricks relates about the most recent war in Afghanistan: "Nothing in the U.S. arsenal looks more like a relic of the Cold War than the lumbering, half-century-old B-52. Yet in the Afghan war, the big eight-engine bomber has become a precision weapon. B-52s have been using data provided by Special Forces troops on the ground to navigate by satellite and drop bombs precisely in designated 1,000-yard-long boxes." Thomas E. Ricks, "Pinpoint Bombing Shifts Role of GI Joe," *The Washington Post* (2 December 2001), A1.

[19] As Colin Gray writes, "There is no such beast as 'strategic' air power and there are no such things as 'strategic' targets. ...[A]ll weapons are tactical in their immediate effect and strategic in the consequences of their actions." Colin S. Gray, *Explorations in Strategy* (Westport, CT: Praeger, 1996), 61.

[20] See Michael Sirak, "U.S. Aiming to Strike Targets 'Within a Minute,'" *Jane's Defence Weekly* (29 September 2004).

is about the discovery of quantifiable regularities that allow for rationalization and prediction. The increasingly technological character of war encourages this rationalization since technology is seen as less abstract and easier to conceptualize and quantify.[21] The consistency of the air medium, especially when compared to the "highly textured geography" of ground warfare, makes air strategy seem even more amenable to mathematical solution.[22] But air power is as much about qualities as it is about quantities. Airmen may aim their weapons at things, but the ultimate effects they seek are qualitative. Success requires consideration of less tangible and irregular variables like leadership, morale, and what Rear Admiral James Stockdale, having spent seven years as a POW in North Vietnam under the rain of American bombs, once called "the pulse of a country."[23] Perception and anomaly, in the end, may be just as important as carefully measured firepower.

Even Solly Zuckerman, the consummate scientific enthusiast, warned of the dangers of the quantified scientific approach to air war in "that it can be stretched too far by attempting too great a logic."[24] Unable to quantify air power's effect on the enemy, airmen have frequently resorted to quantifying friendly effort, counting the number of combat sorties launched or in peacetime, artificially measuring the "reliability" of a well-

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[21] Kenneth P. Werrell, *Chasing the Silver Bullet: U.S. Air Force Weapons Development from Vietnam to Desert Storm* (Washington, D.C.: Smithsonian Books, 2003), 4-5. For proof of the continuation of this tendency today in the application of mathematical models to air warfare, see Corinna M. Jones, "JEFX Analyzes Battlespace Chain Reactions," *Air Force Print News Today* (4 August 2004). Online at http://www.af.mil/news/story_print.asp?_storyID=123008336 (accessed 3 February 2005).
[22] Lawrence Freedman, for example, writes, "While air and sea war have always been reasonably susceptible to operational analysis this is not the same for land war. There were too many variables in play, and terrain was always a major complication." Lawrence Freedman, "A Theory of Battle or a Theory of War?" *Journal of Strategic Studies* 28/3 (June 2005), 428.
[23] Ulysses S.G. Sharp, *Strategy for Defeat: Vietnam in Retrospect* (Novato, CA: Presidio Press, 1998), 256-258. See also Williamson Murray, *Air War in the Persian Gulf* (Baltimore: The Nautical and Aviation Publishing Company of America, 1995), iv; and Benjamin Lambeth, *The Transformation of American Air Power* (Ithaca, NY: Cornell University Press, 2000), 9.
[24] Solly Zuckerman, *From Apes to Warlords* (New York: Harper and Row, Publishers, 1978), 341.

rehearsed plan.[25] Whether measuring effort or effect, numbers in the end may only serve to deceive. Air planners in the spring of 1944, basing their estimates on increases in German aircraft production, underestimated the effects of strategic bombing on the *Luftwaffe* by failing to account for the lag effects of bombing and by misplacing their focus on numbers of aircraft, and not on the availability of trained pilots.[26] It may be true that an F-117 carrying two 2000 pound bombs is 300 times more effective than a B-17 in World War II (as General Buster Glosson contended after DESERT STORM) and that a B-2 with sixteen of these bombs would be 2400 times more effective. What goes unsaid, however, is that the United States built 12,000 B-17s and 18,000 B-24s, but only twenty-one of the incomparably expensive B-2s, and was therefore much more willing to use and lose them.[27]

Economists became more involved in the rationalization of air warfare during the Cold War as emphasis shifted from solving military problems mathematically to determining which components of these problems could be optimized economically.[28] But warfighting is not economics and the demands of effectiveness in war collide with the economists' concern for cost-benefit ratios.[29] The economic approach is a linear

[25] For the most recent example, see T. Michael Moseley, *Operation IRAQI FREEDOM: By the Numbers* (Shaw Air Force Base, SC: Combined Forces Air Component, Assessment and Analysis Division, 30 April 2003). Available at http://www.globalsecurity.org/military/library/report/2003/uscentaf_oif_report_30apr2003.pdf (accessed 27 November 2005).
[26] Craven and Cate, v. 2, 708.
[27] David R. Mets, *The Long Search for Surgical Strike: Precision Munitions and the Revolution in Military Affairs* (Maxwell AFB, AL: Air University Press, 2001), 64, note 108.
[28] Martin J. Collins, *Cold War Laboratory: RAND, the Air Force, and the American State, 1945-1950* (Washington, D.C.: Smithsonian Institution Press, 2002), 220-221.
[29] Edward N. Luttwak, *Strategy: The Logic of War and Peace* (Cambridge, MA: The Belknap Press of Harvard University Press, 2001), 41. As Colin Gray has so artfully written, "The strategist must cope with an uncertain exchange rate between military effort and political effect." Colin S. Gray, *Defining and Achieving Decisive Victory* (Carlisle, PA: Strategic Studies Institute, April 2002), 17.

approach, incompatible with the nonlinearity of air warfare.[30] The economic analyst tends, as Bernard Brodie points out, to be devoid of historical understanding and is "[i]nsensitive to and often intolerant of political considerations that get in the way of his theory and calculations."[31] Even the most rational of the war economists, Robert McNamara, agreed that economic analysis is in the end insufficient: "I don't care if you're talking about friendly fire or whatever military operations are so much more complex than civilian operations. The variables are greater, the causal relationships between action and the effect on a variable are less clear. The result is that human beings are fallible, misjudgments, miscalculations, and mistakes are made far more often in military operations than is generally accepted."[32]

The ultimate in the trend toward rationalization is the application of econometrics to air warfare. Econometrics gives quantified estimates of the effects of incremental changes of "independent" variables on a "dependent" variable. But effects in war are rarely the result of a single cause and each independent variable is to some extent dependent on the values of other variables (the problems of *endogeneity* and *simultaneous determination*). Static econometric models and their *ceteris paribus* assumption do not accurately model the open and dynamic reality of warfare where all is in constant flux.[33] Because two things happen sequentially (e.g., an enemy surrenders following a change in the pattern of bombing) does not guarantee that the two events are

[30] Earl H. Tilford, Jr., *Setup: What the Air Force Did in Vietnam and Why* (Maxwell AFB, AL: Air University Press, 1991), 288.
[31] Bernard Brodie, *War and Politics* (New York: Macmillan Publishing Co., Inc., 1973), 475.
[32] Quoted in George M. Watson, Jr. and Herman S. Wolk, "Whiz Kid: Robert S. McNamara's World War II Service," *Air Power History* 50/4 (Winter 2003), 11.
[33] As a member of the Enemy Objectives Unit wrote during World War II, "The formulation of bombing policy is a fairly complex subject. It demands the combination of a massive flow of intelligence, with a feeling for changing bombing capabilities, and the changing sequence of war strategy and timing, in its

causally related (the problem of *spurious correlations*). Furthermore, because effects in air warfare are not instantaneous and outcomes "lag" over time, the absence of an effect in the wake of some cause is no guarantee of a lack of correlation.

Econometrics offers straight-line estimates of average effects that are undeviating despite changes in the surrounding environment. The slope relating air power inputs to its effectiveness, however, is not constant, but rather nonlinear and varying with changes in the operational environment. A small number of bombs might produce a large effect (as in disabling the Iraqi power network in DESERT STORM) or a large number of bombs might produce little or no effect (as in the jungles of Vietnam during ROLLING THUNDER). The relationship between delivering bombs on target and achieving desired effects shifts not only with changes in variables that are accounted for, but also with changes in variables that go "unobserved." In the Army Air Force's scientific study of bombing accuracy after World War II, these "residual" variables included bombsight malfunction, difficulty in recognizing the aiming point, malfunction of automatic flight control equipment, bombsights not properly set, bomb smoke that concealed the target, traffic interference, and cloud cover – precisely those intervening conditions that make precision and certainty in air warfare such a difficult proposition.[34] Air warfare, it would seem, is the econometrician's worst case.[35]

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broadest sense." Economic Objectives Unit, *War Diary*, R&A Branch, OSS London, Vol. 5, 10. AFHRA file no. 520.056-167.

[34] Thomas I. Edwards and Murray A. Geisler, "The Causes of Bombing Errors as Determined from Analysis of Eighth Air Force Combat Operations," Headquarters, Army Air Forces, 15 July 1947, 47-48. AFHRA file no. 143.504-3. As the authors wistfully commented, "With complete reporting, it would probably be possible to account more fully for the larger bombing errors which have been found in these data. This would have great value in indicating where revisions in training, tactics, or equipment are necessary to reduce this as a source of bombing error."

[35] Luttwak, *Strategy*, 188-189. In all fairness to the discipline of econometrics, there are quantitative methods that account for nonlinear qualitative phenomenon like contingency and interaction. For example, in regression analysis, two variables can be multiplied to assess the "interaction effects" of each variable. Similarly, nonlinear relationships can be "linearized" using logarithmic forms of variables or quadratic

Clausewitz' critique of the rationalists' approach to war, though nearly two hundred years old, is perhaps still the most cogent: "They aim at fixed values; but in war everything is uncertain and calculations have to be made with variable quantities. They direct the inquiry exclusively toward physical quantities, whereas all military action is intertwined with psychological forces and effects. They consider only unilateral action, whereas war consists of a continuous interaction of opposites."[36] It may be true that no thoughtful military strategist would adopt such an extremely rationalist position. But throughout the history of American air power, many *have* adopted the basic undercurrents of this view point: the instructors at ACTS in the 1930's, the advocates of operations research and systems analysis after World War II, as well as the modern-day promoters of network centric warfare and total information awareness. It deserves restating, then, that no matter how precise our tools, the application of military power is still, nearly two hundred years after Clausewitz, a violent and destructive act interposed with chance, passion, and political constraint.

Much in modern air war is clocklike, but it is the persistence of metaphorical clouds that nevertheless frustrates our attempts to scientifically rationalize air warfare. Given the nonlinear nature of war, the nonlinear scientific paradigm offers a much-needed supplement to traditional scientific approaches. Chief among the many benefits the new paradigm has to offer is a greater appreciation for uncertainty in warfare. Competing military systems are coevolving and *epigenetic* – results of military actions

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functions in regression analyses. Although econometricians may talk about the "precision" of their estimates, these manipulations of econometric models nevertheless rely on necessarily imprecise quantitative measurements of qualitative phenomena that are at best only approximations. See Jeffrey M. Woolridge, *Introductory Econometrics: A Modern Approach* (Mason, OH: Thomson Southwestern, 2002), 187-196.

[36] Clausewitz, *On War*, 136. See also Harry G. Summers, Jr., *On Strategy: A Critical Analysis of The Vietnam War* (New York: Dell Publishing Co., Inc., 1982), 82.

depend not only upon initial conditions, but also upon interactions between these systems and their surrounding environment.[37] Both subsequent conditions and final outcomes are emergent and can rarely be determined in advance. Uncertainty, therefore, results not just from a lack of detailed information, but also from the inherent nature of the environment. Success within this environment requires an acceptance of this uncertainty and a comfort in operating under its ever present veil.

Sensitivity to war's nonlinearity can also give greater insight into the nature of the problems we face and the potential for air power solutions. The problems of war are radical examples of Horst Rittel and Melvin Webber's "wicked" problems – problems that confound definitive formulation, each with its own unique social context, where actions always have more than one effect, and solutions require value-based tradeoffs. In solving wicked problems, there is rarely "one best way" and seemingly efficient solutions frequently create waves of other problems.[38] In air warfare as with other wicked problems, ultimate effects are never black and white and arriving at the various shades of "victory" may require many different paths. Populations of air strategies, therefore, are usually better than any single strategy; the true value of parallel warfare may not be in the speed in which air power is applied, but rather in the parallelism, where several solutions employed simultaneously are better than just one.[39] Identifying the problems of war as wicked problems also underscores the value of joint, interagency, and multinational

[37] On the concept of *epigenesis*, see Edward O. Wilson, *Consilience: The Unity of Knowledge* (New York: Alfred A. Knopf, Publisher, 1998), 193.
[38] Horst W.J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4 (1973), 155-169.
[39] This notion is in full accord with Ashby's Law of Requisite Variety, which states that complex problems can only be solved by systems that are at least equally as complex. See Gareth Morgan, *Images of Organization* (Thousand Oaks, CA: SAGE Publications, 1997), 112-113; and James Moffat, *Complexity Theory and Network Centric Warfare* (Washington, D.C.: Command and Control Research Project, 2003), 163.

solutions – strategies involving single services, agencies, or even nations will rarely match the synergy of combined approaches. The nonlinear paradigm thus also suggests a corrective for the delirium of "military metaphysics," defined by C. Wright Mills as "the cast of mind that defines international reality as basically military."[40] Given the complex and interdependent nature of international reality, air power alone (and military power more generally) may prove inappropriate to the international problem it is matched against.

In a future where the nonlinear paradigm informs military minds, military theory and its application would shift from the control paradigm of linearly connected cause and effect. Detailed and deterministic planning would be replaced by a continuous process of learning and adjustment in which planners and commanders "feed forward" plans and purposes while combat units "feed back" information about coevolving adversaries and the surrounding operational environment. The overall "fitness" of self-organizing military systems seeking common strategic and political purposes would take priority over the technical aspects of military operations. Military assessments would emphasize "measures of effectiveness" over "measures of performance."[41] Air planners would see targeting as a process of not just mechanics, but also of values and purposes. Nonlinear-minded airmen would seek not only precision in their weapons, but also variation, flexibility, and adaptability in the ways in which they use these weapons.

[40] C. Wright Mills, *The Power Elite* (Oxford University Press, 2000), 222.
[41] For a discussion of the roles of Measures of Performance (MOPs) and Measures of Effectiveness (MOEs) in effects-based operations, see The Joint Warfighting Center, *Pamphlet 7: Operational Implications of Effects-based Operations* (Norfolk, VA: United States Joint Warfighting Command, 17 November 2004), 16-17. http://www.dtic.mil/doctrine/jel/other_pubs/jwfcpam7.pdf (accessed 6 Dec 2005).

Adaptation – value-optimizing solutions in the context of constraints – is critical to success in the nonlinear environment of war.[42] Meticulous-mindedness should therefore be balanced with creative intelligence in the measure of future airmen.[43] Creative military solutions may sometimes lead to dead ends; the extra resources required for adaptive behaviors are also inherently inefficient. Although inefficient, creativity and adaptation are keys to maintaining competitive strategic advantage. Adaptation and adjustment are necessary to sustain the potentially positive effects of air power as the enemy diverges from prewar strategies and assumptions. The accelerating pace of technological innovation that quickly makes accepted routine obsolete only underscores the necessity of adaptation.[44]

Adaptation is admittedly not easy, especially in military bureaucracies where change competes with the sunken costs of established doctrine.[45] When the experience of war challenges established routine, commanders can choose either to invalidate their doctrine or invalidate the applicability of their experience.[46] As General Haywood Hansell noted in World War II, "There is a thin line between stubborn and stupid adherence to a preconceived idea on one hand, and courageous persistence in the face of initial reverses on the other. The commander who correctly gauges the proper line of action, who remembers that his enemy is also being hurt, and who is driven by a

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[42] Gabriel A. Almond and Stephen J. Genco, "Clouds, Clocks, and the Study of Politics," *World Politics* 29/4 (July 1977), 518.
[43] See J.F.C. Fuller, *Generalship, Its Diseases and Their Cures: A Study of the Personal Factor in Command* (Harrisburg, PA: Military Service Publishing Co., 1936), 33-35. See also Williamson Murray and Mark Grimsley, *The Making of Strategy: Rules, States, and War* (Cambridge, MA: Cambridge University Press, 1994).
[44] Richard P. Hallion, "Doctrine, Technology, and Air Warfare: A Late Twentieth-Century Perspective," *Airpower Journal* 1/2 (Fall 1987), 16-17.
[45] Mrozek, *Air Power and the Ground War in Vietnam*, 1.
[46] Donald J. Mrozek, *The U.S. Air Force After Vietnam: Postwar Challenges and Potential for Responses* (Maxwell AFB, AL: Air University Press, 1988), 7-10.

relentless will to win – generally does win."[47] Dogged persistence in the face of evidence that goes against proven routine often has its merits. American airmen in the past, however, have been too quick to invalidate their experiences as anomaly, declaring "never again" (as in Korea, Vietnam, and Kosovo) at the expense of adaptation and greater operational effectiveness.[48] Future airmen informed by the nonlinear paradigm will better appreciate anomaly as a timeless characteristic of air warfare and will recognize the need for continuous change.

Those who have felt the effects of American air power have already grasped the need for constant transformation – our success has effectively raised their levels of consciousness. Precision air power is one among many forces that have driven opponents toward strategies of terrorism and guerilla warfare. RAND analyst T. Finley Burke, commenting on the implications of precision-guided munitions in 1977, foresaw a conflict dominated by "the control of heavy fire of air-launched standoff missiles by a dispersed guerilla-like ground force, [leading to] the waging of a drawn-out war of attrition."[49] Burke's vision arguably matches the ongoing conflict in Afghanistan against the remnants of al Qaeda and the Taliban and the continuing counter-insurgency campaign in Iraq. The nonlinear paradigm gives many insights into the nature of our own systems and their operating environment. Yet even more important is the deeper understanding this viewpoint offers about the nature of our new opponents and their

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47 Haywood S. Hansell, Jr., *The Air Plan That Defeated Hitler* (Atlanta: Higgins-MacArthur/Longino & Porter, Inc., 1972), 136-137.

48 As Robert Utley relates, this was just as true for the American army fighting on the frontier in the 19th century as it was for the air forces in the twentieth century: "For a century the army fought Indians as if they were British or Mexicans or Confederates. Each Indian war was expected to be the last, and so the generals never developed a doctrine or organization adapted to the special problems posed by the Indian style of fighting." Robert M. Utley, *Cavalier in Buckskin: George Armstrong Custer and the Western Military Frontier* (Norman, OK: University of Oklahoma Press, 1988), 206.

emergent strategies for coping with American air power. Combined with the latest technological capabilities like small-diameter guided bombs and laser weapons, new ways of thinking about precision air power will lead to new methods for dealing with the challenges posed by "asymmetric" opponents.

Precision air power has worked in Afghanistan and Iraq and is getting better.[50] The frequently touted "transformation" of American air power, however, will remain incomplete until airmen adopt a nonlinear mindset, not only finding ways to positively exploit nonlinearity, but also becoming more comfortable with the uncertain and indeterminate nature of air warfare.[51] The paradigm is potentially on the verge of winning out in the American military. Many of the elements of the nonlinear mindset can be found in the concepts of "enemies as systems" and "effects-based operations" that have taken hold in air power theory, as well as in the emerging methods of "adaptive planning" and "systemic operational design" under consideration in the wider joint community.[52] Maintaining momentum in the move away from the mechanistic paradigm of air warfare and institutionalizing this new mindset, however, requires one last theoretical push. This, then, has been the intent of this study.

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[49] T. Finley Burke, "The Implications of the PGM Era," paper prepared for the Air University Airpower Symposium, Maxwell AFB, AL, 29-31 March 1977, 19.

[50] By the one recent Air Force tally, 60.4 percent of weapons dropped during Operation ENDURING FREEDOM in Afghanistan and 68 percent during Operation IRAQI FREEDOM were precision weapons, as compared with 40.5 percent during Operation ALLIED FORCE in Kosovo. *The United States Air Force Transformation Flight Plan 2004* (Washington, D.C.: Headquarters USAF, 2004), 61. On the success of air power in Afghanistan, see especially Eric Schmitt and James Dao, "A Nation Challenged: The Air Campaign," *The New York Times*, 23 December 2001, A1.

[51] For "general behavioral guidelines" from the nonlinear sciences for strategy and policy, see especially Andrew Ilachinski, *Land Combat and Complexity, Part II: An Assessment of the Applicability of Nonlinear Dynamics and Complex Systems Theory to the Study of Land Warfare* (Alexandria, Virginia: Center for Naval Analysis, 1996), 57.

[52] See chapter 6 for a discussion of the nonlinear elements of enemies as systems, parallel ops, and effects-based operations. On *adaptive planning*, see Department of Defense, *Joint Publication 5-0: Doctrine for Joint Operation Planning*, Revision, Second Draft (2) (8 October 2004), I-20. On *systemic operational design*, see Shimon Naveh, "Systemic Operational Design: A New Framework for Strategic

Epistemology," available at http://home.no.net/tacops/Taktikk/Kadettargeid/naveh.htm (accessed 16 Sep 2005).

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Curriculum Vita

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